<H1>Additional Objective Questions

<H2> Single Correct Choice Type

1.(C) Isobars.

2.(C) Ra undergoes radioactive decay by emission of the α-particles in succession to resulting in Pd, which belong to Group 14 elements.

3.(C) Half-life of radioactive isotope does not depend upon the amount of the substance.

4.(A) The nuclear reaction involved is

$$^{238}_{90}\text{Th} \rightarrow {}^{212}_{83}\text{Bi} + 4\,{}^{4}_{2}\text{He} + {}^{0}_{-1}e$$

5.(D) For the first order, we have

$$t_{1/2} = \frac{0.693}{k} \qquad (1)$$

Given, $t_{1/2} = 140.$ days.

Substituting in Eq. (1), we get

$$k = \frac{0.693}{140}$$

We know

$$t = \frac{2.303}{k}\log\left(\frac{N_0}{N_t}\right) \qquad (2)$$

Substituting values in Eq. (2), we get

$$560 = \frac{2.303 \times 140}{0.693}\log\left(\frac{1}{x}\right)$$

After solving, we get

$$x = 0.0625 \text{ g}$$

6.(B) Given, $t_{1/2}$ = 6000 years

The rate constant is

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{6000}$$

We know

$$t = \frac{2.303}{k}\log\left(\frac{N_0}{N_t}\right)$$

$\Rightarrow$ $$t = \frac{2.303 \times 6000}{0.693}\log\left(\frac{2}{1}\right)$$

$\Rightarrow$ $$t \simeq 6000 \text{ days.}$$

7.(D) The nuclear reaction involved is

$$^{238}_{92}\mathrm{U} \rightarrow ^{230}_{92}\mathrm{U} + 2\,^{4}_{2}\mathrm{He} + 4\,^{0}_{-1}e$$

8.(A) From half-life equation, we have

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{12.3}$$

We have

$$t = \frac{2.303}{k}\log\left(\frac{N_0}{N_t}\right) \qquad (1)$$

Substituting the values in Eq. (1), we get

$$49.2 = \frac{2.303 \times 12.3}{0.693}\log\left(\frac{32}{x}\right)$$

After solving, we get

x = 2 mg

9.(A) 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}C is more. Hence, the age of fossil will increase.

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

$$^{23}_{11}\mathrm{Na} \rightarrow ^{23}_{10}\mathrm{Ne} + ^{0}_{+1}e(\beta^+)$$

11.(B) Neutron-poor nuclides have a mass number less than twice the atomic number of the element; **(B)** is neutron poor, (A) and (D) are neutron rich, and (C) is on the line of stability.

12.(B) We know

$$\text{Avg. atomic weight } = \left[\left(\text{Mass of isotope} \times \text{abundance}\right)_1 + \left(\text{Mass of isotope} \times \text{abundance}\right)_2 + \cdots\right]$$

$$\Rightarrow \qquad Z = \left[(Z-1)\times\frac{x}{100_1} + (Z+2)\times\frac{(100-x)}{100}\right]$$

$$\Rightarrow \qquad 100Z = \left[Zx - x + 100Z - Zx + 200 - 2x\right]$$

$$\Rightarrow \qquad x = \frac{200}{3} = 66.6$$

Therefore, the abundance of the heavier isotope is 100 – 66.6 = 33.3%.

13.(C) β-Particle is emitted in radioactivity by conversion of neutron to proton.

14.(D) The nuclear reaction involved is

$$^{235}_{92}\text{U} + {}^{1}_{0}n \rightarrow {}^{94}_{38}\text{Sr} + {}^{139}_{54}\text{Xe} + 2^{1}_{0}n$$

The mass number in reactant and product is

$$235 + 1 = 94 + 139 + x$$

$$x = 3$$

15.(B) Isobars.

16.(C) The electrons is emitted from nucleus of atom.

17.(A) Positron emission is associated with decay of a neutron-poor nuclide.

18.(C) The nuclear reaction involved is

$$^{13}_{7}\mathrm{N} \rightarrow \ ^{13}_{6}\mathrm{C} + \ ^{0}_{+1}e$$

19.(C) The β particle is $^{0}_{-1}e$.

20.(C) The nuclear reaction involved is

$$^{238}_{92}\mathrm{X} \rightarrow ^{234}_{90}\mathrm{Y} + ^{4}_{2}\mathrm{He}$$

Number of neutrons = 234 – 90 = 144

21.(C) Gamma rays are high energy electromagnetic waves.

22.(A) They all have same number of neutrons

23.(C) From half-life equation, we have

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{1500}$$

We have

$$t = \frac{2.303}{k}\log\left(\frac{N_0}{N_t}\right) \quad (1)$$

Substituting the values in Eq. (1), we get

$$3000 = \frac{2.303 \times 1500}{0.693}\log\left(\frac{1}{x}\right)$$

After solving, we get

$$x = 0.25 \text{ g}$$

24.(D) The nuclear reaction involved is

$$^{235}_{92}\mathrm{U} \xrightarrow{\alpha-\text{decay}} \ ^{231}_{90}\mathrm{Th} \xrightarrow{\beta^{-}-\text{decay}} \ ^{231}_{91}\mathrm{Pa} \xrightarrow{\alpha-\text{decay}} \ ^{227}_{89}\mathrm{Ac}$$

25.(C) The nuclear reaction involved is

$$^{14}_{6}X \rightarrow\ ^{14}_{7}N +\ ^{0}_{-1}e$$

Number of neutrons = 14 – 6 = 8

26.(B) As only mass number is to be decreased by one unit

27.(D) Energy = binding energy of products – binding energy of reactants

28.(C) The α-particle is $^{4}_{2}He$.

29.(A) Neutrons can disintegrate to give a proton and an electron.

30.(D) From half-life equation, we have

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{5}$$

We have

$$t = \frac{2.303}{k}\log\left(\frac{N_0}{N_t}\right) \quad (1)$$

Substituting the values in Eq. (1), we get

$$15 = \frac{2.303 \times 5}{0.693}\log\left(\frac{64}{x}\right)$$

After solving, we get

$$x = 8.0 \text{ g}$$

31.(D) The deflection in magnetic field is due to the charge on particle, since, both α- and β-rays are charge particle, therefore, particles seen after deflection by magnetic field are either α- or β-rays.

32.(B) Conc. after n half-lives = $m_0/2^n = m_0 2^{-n}$

33.(C) We know

$$t = \frac{2.303}{k} \log\left(\frac{N_0}{N_t}\right) \qquad (1)$$

Substituting the values in Eq. (1), we get

$$k = \frac{2.303}{48} \log(16)$$

$$k = 0.0577$$

From half-life equation, we have

$$t_{1/2} = \frac{0.693}{0.0577} = 12 \text{ days}$$

34.(B) Isotopes.

35.(C) The nuclear reaction involved is

$$^{24}_{12}\mathrm{Mg} \rightarrow {}^{23}_{11}\mathrm{Na} + {}^{1}_{1}\mathrm{H}$$

36.(C) Concept based.

37.(B) Decrease in mass number by 4 units and decrease in atomic number by 2 units

38.(C) Concept based.

39.(A) $^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{92}\mathrm{U} + 2{}^{0}_{-1}e^{-}$. Change of 4 units in atomic mass is compensated by one α-particle but there should be emission of two β- particles also to compensate atomic number.

40.(C) The nuclear reaction is

$$^{238}_{92}\mathrm{U} \rightarrow {}^{206}_{82}\mathrm{X} + 8{}^{4}_{2}\mathrm{He} + 6{}^{0}_{-1}e$$

n/*p* ratio = 124/82 = 62/41

41.(B) For stability *n*/*p* ratio should be close to one.

In case of $_{5}^{10}\mathrm{B}$

$$\frac{\text{neutron number}}{\text{proton number}}=\frac{10-5}{5}=1$$

In case of $_{4}^{10}\mathrm{B}$

$$\frac{\text{neutron number}}{\text{proton number}}=\frac{10-4}{4}=1.5$$

In case of $_{7}^{14}\mathrm{N}$

$$\frac{\text{neutron number}}{\text{proton number}}=\frac{14-7}{7}=1$$

In case of $_{8}^{16}\mathrm{O}$

$$\frac{\text{neutron number}}{\text{proton number}}=\frac{16-8}{8}=1$$

42.(A) Isotopes have same atomic numbers but different mass numbers.

$$_{Z}^{A}\mathrm{X}\rightarrow {}_{Z}^{A-1}\mathrm{X}+{}_{0}^{1}n$$

43.(A) Let half-life period be *T*.

Number of atoms left after n half-lives is given by

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

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

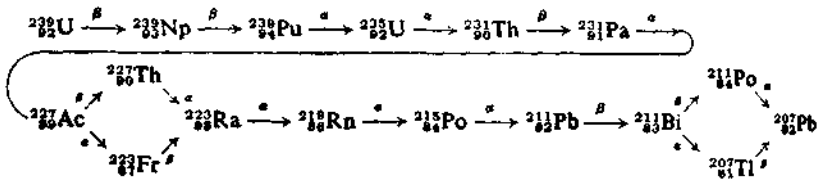
$$\left(\frac{1}{2}\right)^2=\left(\frac{1}{2}\right)^n \quad \text{or} \quad n=2$$

As number of half-lives,

$$n=\frac{t\,(\text{time of disintegration})}{T\,(\text{half life period})}$$

$$T=\frac{t}{n}=\frac{2}{2}=1\,\text{hour}$$

44.(B) The nuclear reaction involved are



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45.(B) Since, β-rays have highest charge to mass ratio, therefore, they experience highest deflection by magnetic field.

46.(B) The nuclear reaction involved is

$$^{6}_{3}\mathrm{Li} + ^{1}_{0}n \rightarrow ^{4}_{2}\mathrm{He} + ^{3}_{1}\mathrm{H}$$

47.(C) The nuclear reaction involved is

$$^{27}_{13}\mathrm{Al} + ^{4}_{2}\mathrm{He}\ ^{31}_{15}\mathrm{P} + n^{0}$$

<H2> Multiple Correct Choice Type

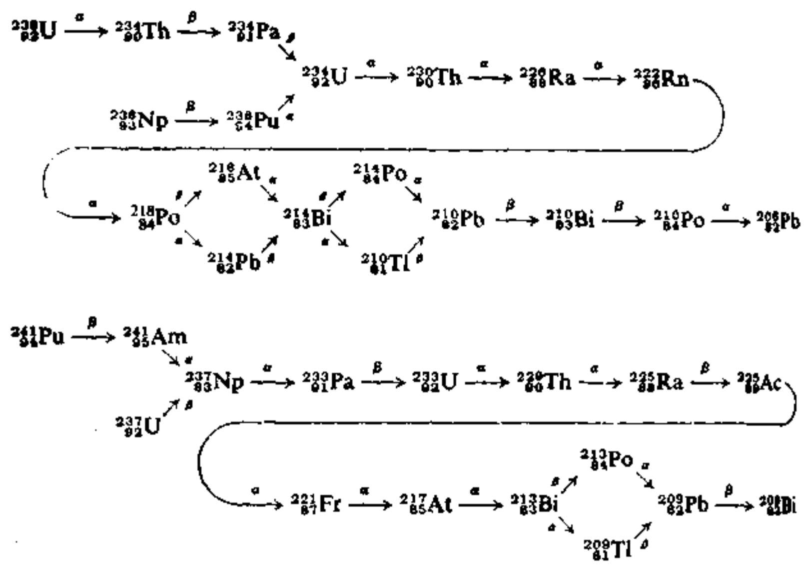
1.(A, B, C) Concept based.

2.(A, C) Since, deuterons are heavier than neutrons, therefore, they are poor bombarding particles than neutrons. ^{239}Pu is the daughter nuclei produced by ^{238}U in breeder reactor.

3.(A, D) Neutron-rich nuclides will have a mass number greater than twice the atomic number of the element; (A) and (B) are neutron rich, (C) is neutron poor, and (D) is on the line of stability.

4.(A, B, C) Same atomic number but different mass number.

5.(A, C) The nuclear reaction involved is



6.(A, C) The nuclear reaction involved is

$$X \rightarrow Y + {}_{-1}^{0}e \rightarrow Z + {}_{2}^{4}He$$

7.(A, B) The most radioactive element present in pitchblende is not uranium, since, the unfiltered uraninite is more radioactive than pure uranium. Since, the gamma-rays are highly energetic electromagnetic waves, therefore, emission of γ-rays changes the mass number but no atomic number.

8.(A, C, D) α-Emission: ${}_{Z}X^{A} \xrightarrow{-\alpha} {}_{Z-2}Z^{A-4}$

ß-Emission: ${}_{Z}X^{A} \xrightarrow{-\beta} {}_{Z+1}Y^{A}$

Positron emission: ${}_{Z}X^{A} \xrightarrow[-\,{}_{+1}^{0}e]{} {}_{Z-1}D^{A}$

Electron capture: ${}_{Z}X^{A} \xrightarrow{+\,{}_{-1}^{0}e} {}_{Z-1}D^{A}$

9.(C, D) Electron emission is associated with decay of a neutron-rich nuclide.

10.(B, C) This reaction represents a nuclear fission reaction, where a heavy particle disintegrates to form a lighter particle along with alpha particle. The two electrons lost combine with positron to release energy and get annihilated.

11.(B, C) Same mass numbers but different atomic numbers.

12.(A, D) We have to keep mass number and atomic number same on both the sides so in (A) and (D) we have to add neutron to right-hand side.

13.(C, D) In nuclear fission, the mass loss through the daughter nuclei's, while in nuclear fusion the mass get add up. Transuranic elements are those elements which come after uranium or having atomic number greater than 92 which is atomic number of uranium.

14.(A, D) Concept based.

15.(A, C) On emitting α particle, the mass number decreases by 4 units while the atomic number by 2 units.

16.(A, C) Because they have isotopes, which have non-integral masses.

17.(C, D) α-Particle is He^{2+} and β-particle is e^{-1}.

18.(B, D) Isotones have same number of neutrons.

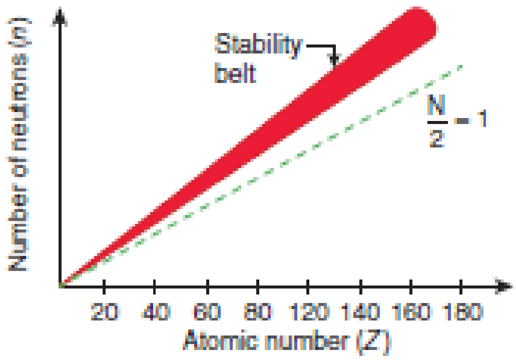
<H2> Assertion–Reasoning Type

1.(A) 82 is the atomic number of Pb after this all radioactive isotopes undergoes α-decay.

2.(A) Since, ^{14}C have more number of neutrons than protons, therefore, it undergoes ß-decay.

3.(B) The neutron–proton (n/p) ratio up to atomic number 20 is 1. For $^{30}_{13}Al$, n/p = 17/13 = 1.3 > 1, so it is unstable.

4.(A) If the curve does not bend towards the x-axis then proton–proton repulsion would overcome the attractive forces of proton and neutron, therefore, the curve bends down.



5.(A) Since, ß-particle are lighter than α-particles, therefore, in electric field, they deflect more.

<H2>Comprehension Type

1.(B) Since, in decay of ^{235}U, ^{206}Pb does not evolved, therefore, this ratio cannot be used for determining the age of a rock.

2.(B) From the given reaction, the oxygen released is coming from water, because, the oxygen present in carbon dioxide is used to generated pyruvate.

3.(B) Since, the carbon in carbon dioxide is ^{14}C, therefore, the carbohydrate formed also contains ^{14}C.

4.(B) From half-life equation, we have

$$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{4.5 \times 10^9}$$

We have

$$\frac{\text{Number of atoms of } \text{Pb}^{206} \text{ formed } (N_{\text{Pb}})}{\text{Number of atoms of } \text{U}^{238} \text{ left } (N_{\text{U}})} = e^{-\lambda t} - 1$$

Taking antilog of above equation, we get

$$t = \frac{1}{\lambda}\left[\ln\left(1 + \frac{N_{\text{Pb}}}{N_{\text{U}}}\right)\right] \quad (1)$$

From the mole concept, we have

$$\frac{N}{N_{\mathrm{A}}} = \frac{m}{M}$$

For 23.8 g of ^{238}U

$$N_{\mathrm{U}} = \frac{23.8}{238} \times 6.023 \times 10^{23} \text{ atoms of } {}^{238}\mathrm{U}.$$

Similarly, for 20.6 g ^{206}Pb

$$N_{\mathrm{Pb}} = \frac{20.6}{206} \times 6.023 \times 10^{23} \text{ atoms of } {}^{206}\mathrm{Pb}.$$

Substituting the values in Eq. (1), we get

$$t = \frac{4.5 \times 10^{9}}{0.693} \left[\ln \left(1 + \frac{6.023 \times 10^{22}}{6.023 \times 10^{22}} \right) \right]$$

After solving, we get

$$t = 4.5 \times 10^{9} \text{ years}$$

5.(A) From half-life equation, we have

$$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{4.5 \times 10^{9}}$$

We have

$$\frac{\text{Number of atoms of Pb}^{206} \text{ formed } (N_{\mathrm{Pb}})}{\text{Number of atoms of U}^{238} \text{ left } (N_{\mathrm{U}})} = e^{-\lambda t} - 1$$

Taking antilog of above equation, we get

$$t = \frac{1}{\lambda} \left[\ln \left(1 + \frac{N_{\mathrm{Pb}}}{N_{\mathrm{U}}} \right) \right] \qquad (1)$$

From the mole concept, we have

$$\frac{N}{N_{\mathrm{A}}} = \frac{m}{M}$$

For 23.8 g of ^{238}U

$$N_{\mathrm{U}} = \frac{x}{238} \times 6.023 \times 10^{23} \text{ atoms of } {}^{238}\mathrm{U}.$$

Similarly, for 20.6 g ^{206}Pb

$$N_{\text{Pb}} = \frac{0.1x}{206} \times 6.023 \times 10^{23} \text{ atoms of } {}^{206}\text{Pb}.$$

Substituting the values in Eq. (1), we get

$$t = \frac{4.5 \times 10^{9}}{0.693}\left[\ln\left(1 + \frac{0.1x \times 6.023 \times 10^{23}}{206} \times \frac{238}{x \times 6.023 \times 10^{23}}\right)\right]$$

After solving, we get

$$t = 7.09 \times 10^{8} \text{ years}$$

6.(B) Isotopes have same atomic number but different mass number so during α-decay the atomic number will be decreased by 2 units and 2 β decay will increase the atomic number by 1 unit. So only the mass number will be decreased by four units and the atomic number will be the same.

7.(C) Isodiaphers have different atomic numbers and mass numbers but same neutron excess ${}^{39}_{19}\text{K}$ and ${}^{19}_{9}\text{F}$ $(A - 2Z = 1)$; ${}^{235}_{92}\text{U}$ and ${}^{231}_{90}\text{Th}$ $(A - 2Z = 51)$

8.(D) Isobars have same mass number but different atomic number, on β decay the atomic number only changes and not the mass number.

9.(A) In case of α decay mass number decreases by 4 units and atomic number by 2 units and in case of β decay mass number remains the same but atomic number increases by 1 unit. (3 – 2 + 1 = 2)

10.(D) Since, the series are 4*n*, 4*n* + 1, 4*n* +2, and 4*n* + 3 series, therefore, the mass of two consecutive members of a series have a difference of 4.

11.(A) As the mass number has been decreased by 32 (8 × 4) and the atomic number by 5 (2 × 8 = 16 for α particle and –6 (for β particles) 16 – 6 =10)

12.(D) The given process involved of loss of 4 electrons.

13.(C) A 4*n* + 1 series once existed, which started with ^{237}Np and decayed to form the only stable isotope of bismuth, ^{209}Bi.

14.(C) Found in uranium 238 series.

<H2> Integer Answer Type

1.(2) The nuclear reaction involved is

$$^{A}_{Z}\text{M} \rightarrow ^{4}_{2}\text{He} + 2^{0}_{-1}e + ^{A-4}_{Z}\text{M}$$

2.(8) The nuclear reaction involved is

$$^{14}_{6}\text{C} \rightarrow ^{14}_{7}\text{N} + ^{0}_{-1}e$$

3.(4) Solving the equations

$$^{239}_{94}\text{Pu} \rightarrow ^{206}_{82}\text{Pb} + \alpha + \beta + ^{1}_{0}n$$

239 = 206 + 4x + 0y + 1z

94 = 82 + 2x – y + 0z

We get y = 4

4.(6) Given, half-life of Q = 4.5 h

From half-life equation, we have

$$k_{\text{P}} = \frac{0.693}{t_{1/2}} = \frac{0.693}{9} = 0.077\ \text{h}^{-1}$$

$$k_{\text{Q}} = \frac{0.693}{t_{1/2}} = \frac{0.693}{4.5} = 0.154\ \text{h}^{-1}$$

Therefore, $k = k_Q + k_P = 0.077 + 0.154 = 0.231\ \text{h}^{-1}$

For first order reaction, we have

$$t = \frac{2.303}{k}\log\left(\frac{[\text{A}]_0}{[\text{A}]_t}\right) \qquad (1)$$

From the reactions, we have $\frac{-\text{d}[\text{A}]}{\text{d}t} = (k_\text{P} + k_\text{Q})[\text{A}]$ and $\frac{-\text{d}[\text{Q}]}{\text{d}t} = \frac{k_\text{P}}{k_\text{Q}} = \frac{[\text{P}]}{[\text{Q}]}$

Therefore, $[\text{A}]_t = [\text{A}]_0 - [\text{P}] - [\text{Q}] = 0.308 - 0.077 - 0.154 = 0.077$

Now, for the time after which Q doubles the concentration of A, we have

$$[\text{Q}] = 2\{[\text{A}]_0 - [\text{P}] - [\text{Q}]\}$$

$$[\text{Q}] = 2A_0 - 2[\text{P}] - 2[\text{Q}] \Rightarrow [\text{A}]_0 = \frac{3[\text{Q}] + 2[\text{P}]}{2}$$

$$[\text{A}]_0 = \frac{3 \times (0.154) + 2 \times (0.077)}{2} = 0.308$$

Substituting the values in Eq. (1), we get

$$t = \frac{2.303}{0.231}\log\left(\frac{0.308}{0.077}\right)$$

After solving, we get t = 6 h

<H2> Matrix–Match Type

1.(A) $\rightarrow$ (q); **(B)** $\rightarrow$ (r); **(C)** $\rightarrow$ (p), **(D)** $\rightarrow$ (t); (E) $\rightarrow$ (s)

(A) Isotopes have same atomic number but different mass number.
(B) Isotones have same number of neutrons but different atomic number.
(C) Isobars have same mass number but different atomic number.
(D) Isoters have same number of electrons.
(E) Isodiaphers have different atomic numbers and mass numbers but same neutron excess $^{39}_{19}\text{K}$ and $^{19}_{9}\text{F}$ $(A - 2Z = 1)$; $^{235}_{92}\text{U}$ and $^{231}_{90}\text{Th}$ $(A - 2Z = 51)$

2.(A) $\rightarrow$ (r); **(B)** $\rightarrow$ (s); **(C)** $\rightarrow$ (p), **(D)** $\rightarrow$ (q)

(A) Carbon dating is used to find the age of trees, etc.
(B) ^{60}Co is used in radiation therapy that specifically attack tumor cells, without damaging normal tissue.
(C) In nuclear fission reaction a heavy nucleus is broken down into two heavy or medium fragments and is accompanied by release neutrons and large amount of energy. Atom bomb is based on this principle.

(D) While in nuclear fusion, light nuclei fuse together to form new nuclei that are comparatively heavy and release a large amount of energy. For example, hydrogen bomb.

3.(A) $\rightarrow$ (p), (q); **(B)** $\rightarrow$ (s); **(C)** $\rightarrow$ (r), (t), **(D)** $\rightarrow$ (p), (q)

(A) ${}^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He}\ (\alpha\text{-decay}) \rightarrow {}^{234}_{91}\text{Pa}\,(\beta\,\text{decay})$

(B) The process by which a stable isotope is converted into radioactive element by artificial means (artificial transmutation) is called artificial or induced radioactivity.

(C) ${}^{9}_{5}\text{B} \rightarrow {}^{9}_{4}\text{Be} + {}^{0}_{+1}e\ (\text{positive emission})$

${}^{9}_{5}\text{B} + {}^{0}_{+1}e \rightarrow {}^{9}_{6}\text{C}\ (\text{electron capture})$

(D) ${}^{226}_{88}\text{Ra} \rightarrow {}^{214}\text{Pb}\,(3\alpha\text{-decay}) \rightarrow {}^{214}\text{Po}\,(2\beta\text{-decay})$