NUCLEAR CHEMISTRY [JEE ADVANCED PREVIOUS YEAR SOLVED PAPERS]

JEE ADVANCED

Single Correct Answers Type

1. If uranium (mass number 238 and atomic number 92) emits an α-particle, the product has mass number and atomic number

a. 236 and 92 **b.** 234 and 90
c. 238 and 90 **d.** 236 and 90

(IIT-JEE 1981)

2. An isotope of $_{32}Ge^{76}$ is

a. $_{32}Ge^{77}$ **b.** $_{33}As^{77}$ **c.** $_{34}Se^{77}$ **d.** $_{34}Se^{78}$

(IIT-JEE 1984)

3. The radiations from a naturally occurring radioactive substance, as seen after deflection by a magnet in one direction, are

a. definitely alpha rays
b. definitely beta rays
c. both alpha and beta rays
d. either alpha or beta rays **(IIT-JEE 1984)**

4. The half-life period of a radioactive element is 140 days. After 560 days, one gram of the element will reduce to

a. $\frac{1}{2}$ g **b.** $\frac{1}{4}$ g **c.** $\frac{1}{8}$ g **d.** $\frac{1}{16}$ g

(IIT-JEE 1986)

5. $_{13}Al^{27}$ is a stable isotope. $_{13}Al^{29}$ is expected to disintegrate by

a. α-emission **b.** β-emission
c. Positron emission **d.** Proton emission

(IIT-JEE 1996)

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

a. 0 **b.** 2 **c.** 1 **d.** 3

(IIT-JEE 1999)

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

a. $\beta^{\ominus}$-emission **b.** α-emission
c. $\beta^{\oplus}$-emission **d.** K electron capture

(IIT-JEE 2003)

8. A positron is emitted from $_{11}Na^{23}$. 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)

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

$$_{14}Si^{30} + X \xleftarrow{(i)} {}_{13}Al^{27} \xrightarrow{(ii)} {}_{15}P^{30} + Y \longrightarrow {}_{14}Si^{30} + Z$$

a. proton, neutron, positron
b. neutron, positron, proton
c. proton, positron, neutron
d. positron, proton, neutron **(IIT-JEE 2011)**

Multiple Correct Answers Type

1. The nuclear reaction(s) accompanied with the emission of neutron(s) is/are

a. $_{13}Al^{17} + {}_2He^4 \rightarrow {}_{15}P^{30}$
b. $_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13}$
c. $_{15}P^{30} \rightarrow {}_{14}Si^{30} + {}_1e^0$
d. $_{96}Am^{241} + {}_2He^4 \rightarrow {}_{97}Bk^{244} + {}_1e^0$ **(IIT-JEE 1988)**

2. Decrease in atomic number is observed during

a. alpha emission **b.** beta emission
c. positron emission **d.** electron capture

(IIT-JEE 1998)

3. In the nuclear transmutation

$$^9_4Be + X \rightarrow {}^8_4Be + Y$$

(X,Y) is/are

a. (γ, n) **b.** (p, D) **c.** (n, D) **d.** (γ, p)

(JEE Advanced 2013)

Linked Comprehension Type

Several short-lived radioactive species have been used to determine the age of wood or animal fossils. One of the most interesting substances is $_6C^{14}$ (half-life 5760 years) which is used in determining the age of carbon-bearing materials (e.g. wood, animal fossils, etc.). Carbon-14 is produced by the bombardment of nitrogen atoms present in the upper atmosphere with neutrons (from cosmic rays).

$$_7N^{14} + {}_0n^1 \rightarrow {}_6C^{14} + {}_1H^1$$

Thus carbon-14 is oxidized to CO_2 and eventually ingested by plants and animals. The death of plants or animals put an end to the intake of C^{14} from the atmosphere. After this the amount of C^{14} in the dead tissues starts decreasing due to its disintegration as per the following reaction:

$$_6C^{14} \rightarrow {}_7N^{14} + {}_{-1}\beta^0$$

The C^{14} isotope enters the biosphere when carbon dioxide is taken up in plant photosynthesis. Plants are eaten by animals, which exhale C^{14} as CO_2. Eventually, C^{14} participates in many aspects of the carbon cycle. The C^{14} lost by radioactive decay is constantly replenished by the production of new isotopes in the atmosphere. In this decay-replenishment process, a dynamic equilibrium is established whereby the ratio of C^{14} to C^{12} remains constant in living matter. But when an individual plant or an animal dies, the C^{14} isotope in it is no longer replenished, so the ratio decreases as C^{14} decays. So, the number of C^{14} nuclei after time t (after the death of living matter) would be less than in a living matter. The decay constant can be calculated using the following formula.

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

The intensity of the cosmic rays has remain the same for 30,000 years. But since some years the changes in this are observed due to excessive burning of fossil fuel and nuclear tests.

(IIT-JEE 2006)

1. Why do we use the carbon dating to calculate the age of the fossil?
   - **a.** Rate of exchange of carbon between atmosphere and living is slower than decay of C^{14}
   - **b.** It is not appropriate to use C^{14} dating to determine age
   - **c.** Rate of exchange of C^{14} between atmosphere and living organism is so fast that an equilibrium is set up between the intake of C^{14} by organism and its exponential decay
   - **d.** None of the above
2. What would be the age of the fossil for meaningful determination of its age?
   - **a.** 6 years
   - **b.** 6000 years
   - **c.** 60,000 years
   - **d.** Can be used to calculate any age
3. A nuclear explosion has taken place leading to an increase in the concentration of C^{14} in nearby areas. C^{14} 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 same
   - **d.** $\frac{T_1}{T_2} = \frac{C_1}{C_2}$

Integer Answer Type

1. A closed vessel with rigid walls contains 1 mol of $^{238}_{92}U$ and 1 mol of air at 298 K. Considering complete decay of $^{238}_{92}U$ to $^{206}_{82}Pb$, the ratio of the final pressure to the initial pressure of the system at 298 K is **(JEE Advanced 2015)**
2. 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?

$$^{63}_{29}Cu + ^{1}_{1}H \rightarrow 6^{1}_{0}n + ^{4}_{2}\alpha + 2^{1}_{1}H + X$$

(IIT-JEE 2012)

3. The number of neutrons emitted when $^{235}_{92}U$ undergoes controlled nuclear fission to $^{142}_{54}Xe$ and $^{90}_{38}Sr$ is **(IIT-JEE 2010)**
4. The total number of α and β particles emitted in the nuclear reaction $^{238}_{92}U \rightarrow ^{214}_{82}Pb$ is **(IIT-JEE 2009)**

Assertion-Reasoning Type

Read the following questions and answer as per the direction given below:

- **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.

1. **Assertion (A):** Nuclide $^{30}_{13}Al$ is less stable than $^{40}_{20}Ca$.
   Reason (R): Nuclides having odd number of protons and neutrons are generally unstable. **(IIT-JEE 1998)**
2. **Assertion (A):** 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.
   Reason (R): Proton–proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons in heavier nuclides. **(IIT-JEE 2008)**

Fill in the Blanks Type

1. An element $_ZM^A$ undergoes an α-emission followed by two successive β-emissions. The element formed is .... **(IIT-JEE 1982)**
2. Elements of the same mass number but of different atomic number are known as .... **(IIT-JEE 1983)**
3. The number of neutrons in the parent nucleus which gives N^{14} on beta emission is .... **(IIT-JEE 1985)**
4. A radioactive nucleus decays by emitting one alpha and two beta particles, the daughter nucleus is .... of the parent **(IIT-JEE 1988)**
5. **a.** $_{92}U^{235} + _0n^1 \longrightarrow _{52}A^{137} + _{40}B^{97} + ...$
   b. $_{34}Se^{82} \longrightarrow 2\ _{-1}e^0 + ...$ **(IIT-JEE 2005)**
6. Complete the following:
   i. $_7N^{14} + _2He^4 \longrightarrow _8O^{17} + ...$ **(IIT-JEE 2005)**
   ii. $_{92}U^{235} + _0n^1 \longrightarrow _{55}A^{142} + _{37}B^{92} + ...$

iii. $_{29}Cu^{53} \longrightarrow {}_{28}Ni^{53} + ...$

iv. $2\ {}_1H^3 \longrightarrow {}_2He^4 + ...$

v. $_{96}Cm^{246} + {}_6C^{12} \longrightarrow {}_{102}No^{254} + ...$

vi. $_{94}Pu^{239} + ... \longrightarrow {}_{96}Cm^{242} + {}_0n^1$

vii. $_{34}Se^{82} \longrightarrow ...... + 2\ {}_{-1}e^0$

True / False Type

1. In a given electric field, β-particles are deflected more than α-particles, inspite of α-particles having larger charge. **(IIT-JEE 1993)**

Subjective Type

1. Radioactive decay is a first-order process. Radioactive carbon in wood sample decays with a half-life of 5770 years. What is the rate constant (in years^{-1}) for the decay? What fraction would remain after 11540 years? **(IIT-JEE 1984)**
2. $_{90}Th^{234}$ disintegrates to give $_{82}Pb^{206}$ Pb as the final product. How many alpha and beta particles are emitted during this process? **(IIT-JEE 1986)**
3. An experiment requires minimum beta activity produced at the rate of 346 beta particles per minute. The half-life period of $_{42}Mo^{99}$, which is a beta emitter, is 66.6 hours. Find the minimum amount of $_{42}Mo^{99}$, required to carry out the experiment in 6.909 hours. **(IIT-JEE 1989)**
4. The nuclidic ratio ${}_1^3H$ to ${}_1^1H$ in a sample of water is $8.0 \times 10^{-8} : 1$. Tritium undergoes decay with a half-life period of 12.3 years. How many tritium atoms would 10.0 g of such a sample contain 40 years after the original sample is collected. **(IIT-JEE 1992)**
5. One of the hazards of nuclear explosion is the generation of Sr and its subsequent incorporation in bones. This nuclide has a half life of 28.1 years. Suppose one microgram was absorbed by a new-born child. how much Sr will remain in his bones after 20 years. **(IIT-JEE 1995)**
6. Ac^{227} has a half-life of 22.0 years with respect to radioactive decay. The decay follows two parallel paths, one leading to Th^{227} and the other to Fr^{227}. The percentage yields of these two daughter nuclides are 2.0 and 98.0, respectively. What are the decay constants (λ) for each of the separate paths? **(IIT-JEE 1996)**
7. Write a balanced equation for the reaction of N^{14} with α-particles. **(IIT-JEE 1997)**
8. On analysis a sample of uranium ore was found to contain 0.277 g of $_{82}Pb^{206}$ and 1.667 g of $_{92}U^{238}$. The half-life period of U^{238} is 4.51×10^9 years. If all the lead were assumed to have come from the decay of $_{92}U^{238}$, what is the age of earth? **(IIT-JEE 2000)**
9. Calculate the number of α- and β-particles emitted when $_{92}U^{238}$ changes into radioactive $_{82}Pb^{206}$. **(IIT-JEE 2000)**
10. Cu^{64} (half-life = 12.8 hours) decays by β -emission (38%), $\beta^{\oplus}$-emission (19%), and electron capture (43%). Write the decay products and calculate partial half lives for each of the decay processes. **(IIT-JEE 2002)**
11. Th^{234} disintegrates and emits 6β- and 7β-particles to form a stable element. Find the atomic number and mass number of the stable product. Also identify the element. **(IIT-JEE 2005)**
12. Calculate the total number of α- and β-particles emitted in the nuclear reaction $_{92}U^{238} \rightarrow {}_{82}Pb^{214}$. **(IIT-JEE 2009)**
13. Calculate the number of neutrons emitted when $_{92}U^{235}$ undergoes controlled nuclear fission to $_{54}Xe^{142}$ and $_{38}Sr^{90}$. **(IIT-JEE 2010)**

Answer Key

JEE Advanced

Single Correct Answer Type

1. b. 2. a. 3. d. 4. d. 5. b.
6. d. 7. a. 8. c. 9. a.

Multiple Correct Answers Type

1. a., d. 2. b., c., d. 4. a., b.

Linked Comprehension Type

1. c. 2. b. 3. a.

Integer Answer Type

1. (9) 2. (8) 3. (3) 4. (8)

Assertion–Reasoning Type

1. b. 2. a.

Fill in the Blanks Type

1. ${}^{A-4}_{Z}M$ 2. Isobars 3. 7 4. Isotope
5. (a) $2\ {}_0n^1$ (b) $_{36}Kr^{82}$
6. (i) $_1H^1$ (ii) $2\ {}_0n^1$ (iii) $_{+1}e^0$ (iv) $2\ {}_0n^1$ (v) $4\ {}_0n^1$ (vi) $_2He^4$ (vii) $_{36}Kr^{82}$

True/False Type

1. True

Hints and Solutions

JEE ADVANCED

Single Correct Answer Type

1. b. Emission of an α-particle means mass is decreased by 4 units and charge by 2 units. Thus,

$$_{92}U^{238} \xrightarrow{-\alpha} {}_{90}U^{234} + {}_2^4He$$
(α-particle)

Thus, the mass number = 234

Atomic number = 90

2. a. Atoms having same number of protons are called isotopes.

3. d. A naturally occurring substance may emit either alpha or beta rays.

4. d. $T = n \times t_{1/2}$

$$\therefore \quad n = \frac{T}{t_{1/2}} = \frac{560}{140} = 4$$

$$\text{Now, } N_t = N_0\left(\frac{1}{2}\right)^n = 1\times\left(\frac{1}{2}\right)^4 = \frac{1}{16}\text{g}$$

5. b. The species $_{13}Al^{29}$ (number of neutrons = 16) contains more neutrons than the stable isotope $_{13}Al^{27}$ (number of neutrons = 14). Neutrons on decomposition show β-emission.

$$_0n^1 \longrightarrow {}_1H^1 + {}_{-1}e^0$$
β-particle

6. d. $^{235}_{92}U + {}^1_0n \rightarrow {}^{139}_{54}Xe + {}^{94}_{38}Sr + 3{}^1_0n$

7. a. Isotopic $_{11}Na^{24}$ is less stable than $_{11}Na^{23}$ because it shows radioactive decay (less stability of Na^{24} w.r.t. Na^{23} also based upon 13/11(n/p) ratio. Higher the value higher will be unstability. So it is disintegrated to attain stability).

$$_{11}Na^{24} \longrightarrow {}_{11}Na^{23} + {}_0n^1$$
Less stable Stable Neutron

This neutron on decomposition gives proton and β-particle ($_1n^0$)

$$_0n^1 \longrightarrow {}_1H^1 \text{ or } {}_1P^1 + {}_{-1}e^0$$
Proton β-particle

Hence, isotopic sodium is changed into sodium by means of emission of β-particle and a proton i.e., by β-emission.

8. c. $_{11}Na^{23} \longrightarrow {}_{10}Na^{23} + {}_{-1}e^0$

$$\text{Ratio of } \frac{\text{Atomic mass}}{\text{Atomic number}} = \frac{23}{10}$$

9. a. $_{13}Al^{27} \xrightarrow{\;_2He^4\;} {}_{15}P^{30} + {}_0n^1$ (y)

$_2He^4 \downarrow$ (i) $\downarrow$ (ii)

$_{14}Si^{30} + {}_1P(x)^1$ $_{14}Si^{30} + {}_1e^{+0}$ (z)

∴ x: Protons, y: neutron, z: positron.

Multiple Correct Answers Type

1. a., d.

$$_{13}Al^{27} + {}_2He^4 \longrightarrow {}_{15}P^{30} + {}_0n^1$$
$$_{96}Am^{241} + {}_2He^4 \longrightarrow {}_{97}Bk^{244} + {}_1e^0 + {}_0n^1$$

2. a., c., d.

a. $_ZX^A \xrightarrow{-\alpha} {}_{Z-2}Y^{A-4}$ (α-emission)

b. $_ZX^A \xrightarrow{-\beta} {}_{Z+1}Y^A$ (β-emission)

c. $_ZX^A \xrightarrow{-\;_{+1}e^0} {}_{Z-1}Y^A$ (positron-emission)

d. $_ZX^A + {}_{-1}e^0 \longrightarrow {}_{Z-1}Y^A$ (electron capture)

3. a., b.

$$^9_4Be + \gamma \longrightarrow {}^8_4Be + {}^1_0n$$
$$^9_4Be + {}^1_1H \longrightarrow {}^8_4Be + {}^2_1H$$

Hence (a) and (b) are correct.

Linked Comprehension Type

1. c. It is clear from the 3rd paragraph, which states that in living organisms a dynamic equilibrium is established where the ratio of C^{14} to C^{12} remains constant. The C^{14} which decays into N^{14} is replenished by the produce of new isotopes

2. b. As the half-life of C^{14} is 5760 years, so a 6-year old fossil's age can't be determined. Further this technique cannot be used to date objects older than 30,000 years. After this length of time the radioactivity is too low to be measured.

3. a. $T_1 = \frac{1}{\lambda}\ln C_1$ $T_2 = \frac{1}{\lambda}\ln C_2$

Let the concentration of C^{14} in the fossil be C. In nearby areas concentration of C^{14} in living beings will be C_1 and in far off places C_2, obviously $C_1 > C_2$.

Hence, age of fossil in early areas,

$$T_1 = \frac{1}{\lambda}\ln\frac{C_1}{C} \quad \text{(i)}$$

and age in far off places, $T_2 = \frac{1}{\lambda}\ln\frac{C_2}{C}$ (ii)

From (i) and (ii), $T_1 - T_2 = \frac{1}{\lambda}\ln\frac{C_1}{C_2}$

Since $C_1 > C_2$, R.H.S is positive i.e., $T_1 > T_2$.

Integer Answer Type

1. (9) Number of moles in gas phase, at start (n_i) = 1

$$^{238}_{92}U \rightarrow {}^{206}_{82}Pb + 8{}^4_2He + 6{}^0_{-}\beta$$

Now number of moles in gas phase, after decomposition (n_f) = 1 + 8 = 9 mole

At constant temperature and pressure

$$\frac{P_F}{P_{in}} = \frac{n_F}{n_{in}} = \frac{9}{1} = 9$$

2. (8) $^{63}_{29}Cu + {}_1H^1 \rightarrow 6\,{}_0n^1 + {}^4_2He + 2\,{}_1H^1 + {}^A_ZX$

Mass number: 63 + 1 = 1 × 6 + 4 + 1 × 2 + A

A = 64 – 12 = 52

Atomic number: 29 + 1 = 6 × 0 + 2 + 2 × 1 + Z

Z = 30 – 4 = 26

$^A_ZX = {}^{52}_{26}Fe$

Hence X is in group '8' in the periodic table.

3. (3) $_{92}U^{235} \rightarrow {}_{54}Xe^{142} + {}_{38}Sr^{90} + 3\,{}_0n^1$

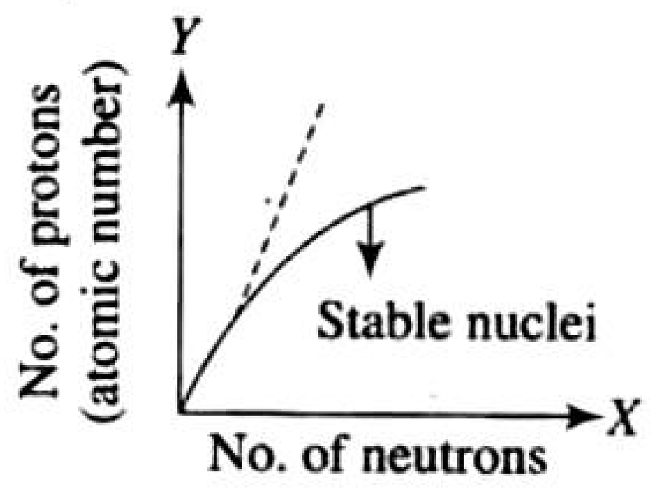
4. (8) $_{92}U^{238} \xrightarrow{-6\alpha} {}_{80}X^{214} \xrightarrow{-2\beta} {}_{82}Pb^{214}, (6\alpha, 2\beta)$, total 8 paritcles.

Assertion-Reasoning Type

1. b. When the n/p ratio is more than 1, then nuclei is unstable but when it is 1, then nuclei is stable. In $_{13}Al^{30}$, $n/p = 17/13 = 1.3$ (i.e., more than 1, so less stable), but in $_{20}Ca^{40}$, $n/p = 1$ (more stable).

Nuclei with odd number of protons and neutrons are generally unstable.

2. a. The stability relationship can be represented by a line with a slope of 45°, i.e., the maximum stability is attained when $n = Z$ right of the curve. A radioactive nuclide would be neutron rich and would decay by β-emission to produce a daughter nucleus with a lower n/p ratio.



For heavier nuclides, p–p repulsions start to offset the attractive forces and an excess of neutrons over protons, required for stability.

Fill in the Blanks Type

1. $_ZM^A \xrightarrow{-\alpha} {}_{Z-2}M^{A-4} \xrightarrow{-\beta} {}_{Z-1}M^{A-4} \xrightarrow{-\beta} {}_ZM^{A-4}$
2. Isobars
3. $_6C^{14} \longrightarrow {}_7N^{14} + {}_{-1}e^0$
4. Isotope
5. **a.** $_{92}U^{235} + {}_0n^1 \longrightarrow {}_{52}A^{137} + {}_{40}B^{97} + 2\,{}_0n^1$

   b. $_{34}Se^{84} \longrightarrow 2\,{}_{-1}e^0 + {}_{36}Kr^{82}$
6. **i.** $_7N^{14} + {}_2He^4 \longrightarrow {}_8O^{17} + \ldots$ or $_7N^{14} + {}_2He^4 \longrightarrow {}_8O^{17} + {}_ZX^m$

   Equating mass numbers on both sides

   $14 + 4 = 17 + m \Rightarrow m = 1$

   Equating atomic number on both sides,

   $7 + 2 = 8 + Z \Rightarrow Z = -1$

   ∴ X is $_1X^1$, i.e., $_1H^1$.

   or $_7N^{14} + {}_2He^4 \longrightarrow {}_8O^{17} + {}_1H^1$

   ii. $_{92}U^{235} + {}_0n^1 \longrightarrow {}_{55}A^{142} + {}_{37}B^{92} + \ldots$

   Equation is $_{92}U^{235} + {}_0n^1 \longrightarrow {}_{55}Cs^{142} + {}_{37}Rb^{97} + 2\,{}_0n^1$

   iii. $_{29}Cu^{53} \longrightarrow {}_{28}Ni^{53} + {}_ZX^m$

   Equating atomic number on both sides and mass number on both sides

   $Z = 1 \quad m = 0$

   ∴ $_{29}Cu^{53} \longrightarrow {}_{28}Ni^{53} + {}_{+1}e^0$

   iv. $2\,{}_1H^3 \longrightarrow {}_2He^4 + {}_ZX^m$

   Equating atomic number on both sides and mass number on both sides

   $Z = 1 \quad m = 2$

   ∴ $2\,{}_1H^3 \longrightarrow {}_2He^4 + 2\,{}_0n^1$

   v. Equating atomic number and mass number on both sides

   $_{96}Cm^{246} + {}_6C^{12} \longrightarrow {}_{102}No^{254} + 4\,{}_0n^1$

   vi. Equating atomic number and mass number on both sides

   $_{94}Pu^{239} + {}_2He^4 \longrightarrow {}_{96}Cm^{242} + {}_0n^1$

   vii. Equating atomic number and mass number on both sides.

   $_{34}Se^{82} \longrightarrow {}_{36}Kr^{82} + 2\,{}_{-1}e^0$

True / False Type

1. **True:**

   β-particles are deflected more than α-particles because they have very-very large e/m value as compared to α-particles due to the fact that electrons are much lighter than He^{2+} species.

Subjective Type

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

   Half life, $t_{1/2} = 5770$ years

   Let the original sample be 1 gram.

   Therefore, after every 5770 years one-half of radioactive carbon would decay or disintegrate.

   Thus, 1 g sample becomes ½ g after 5770 years and $\dfrac{1}{2} \times \dfrac{1}{2} = \dfrac{1}{4}$ left after 11,540 years.

   Therefore, 25% of radioactive carbon remains after 11540 years.

   Rate constant, k for first-order reaction,

   $$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{5770} = 1.2 \times 10^{-4}\ \text{year}^{-1}$$

2. Let x α- and y β-particles are given out during the change.

   ∴ $_{90}Th^{234} \longrightarrow {}_{82}Pb^{206} + x\,{}_2He^4 + y\,{}_{-1}e^0$

   Equating mass number on both sides,

   $234 = 206 + 4x + y \times 0$ or $4x = 234 - 206 = 28$

   ∴ $x = \dfrac{28}{4} = 7$

   Equating atomic number on both sides

   $90 = 82 + 2x + y(-1) = 82 + 2 \times 7 + y(-1) = 82 + 14 + (-y)$

   $y = 96 - 90 = 6$

   ∴ Number of α-particles = 7 and number of β-particles = 6

3. To carry out experiment,

   Rate of β-emission required = 346 particles min^{-1}

   Rate = k · N or desired number of atoms to carry out experiment after 6.909 hr

   $$= \frac{\text{Rate}}{K} = \frac{346 \times 66.6 \times 60}{0.693} = 1.995 \times 10^6 \text{ atom}$$

   Now, when $N = 1.995 \times 10^6$ atoms of Mo at $t = 6.909$ hr, N_0 can be evaluated as

   $$t = \frac{2.303}{k} \log \frac{N_0}{N}$$

   $$6.909 = \frac{2.303 \times 66.6}{0.693} \log \frac{N_0}{N}$$

   ∴ $\dfrac{N_0}{N} = 1.0745$

   ∴ $N_0 = N \times 1.0745$

   $= 1.995 \times 10^6 \times 1.0745 = 2.1436 \times 10^6$ atoms of Mo^{99}

   Weight of Mo required to carry out experiment in 6.909 hr

   $$= \frac{2.1436 \times 10^6 \times 99}{6.023 \times 10^{23}} \text{g} = 3.56 \times 10^{-16}\ \text{g}$$

4. The ratio of $H^3 : H^1 :: 8 \times 10^{-18} : 1$

   ∵ No. of H atoms in 18 g H_2O = 2N

$\therefore$ No. of H^3 atoms in 18 g of H_2O

$= 2N \times 8 \times 10^{-18} = 2 \times 6.023 \times 10^{23} \times 8 \times 10^{-18}$ atoms

$\therefore$ No. of H^3 atoms in 10 g H_2O

$$= \frac{2 \times 6.023 \times 10^{23} \times 8 \times 10^{-18} \times 10}{18} \text{ atoms}$$

$= 5.354 \times 10^6$ atoms

No. of atoms left after 40 years are derived as follows using the relation

$$t = \frac{2.303}{\lambda} \log \frac{N_0}{N_t}$$

$$40 = \frac{2.303 \times 12.3}{0.693} \log \frac{5.354 \times 10^6}{N_t}$$

$\therefore$ $N_t = 5.624 \times 10^5$ atoms

5. Initial amount of Sr^{90} $(N_0) = 1$ μg

Amount of Sr^{90} after 20 year (N_t) = [?]

Used time (t) = 20 years

Half-life period of Sr^{90} $(t_{1/2})$ = 28.1 years

Decay constant $(\lambda) = \frac{0.693}{t_{1/2}} = \frac{0.693}{28.1} \text{year}^{-1}$

For Sr^{90}: (Because all radioactive decays are the examples of first-order reaction)

$$\frac{0.693}{28.1} = \frac{2.303}{20} \log \frac{N_0}{N_t}$$

On solving,

$$\log_{10} \frac{N_0}{N_t} = 0.2141$$

or $\log_{10} \frac{N_t}{N_0} = -0.2141$

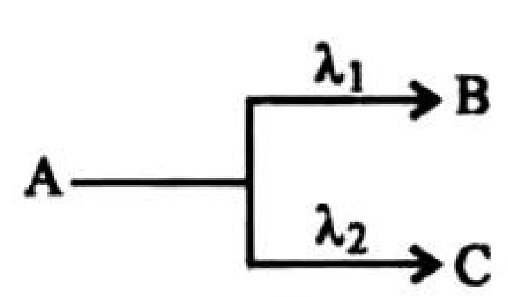
or $\frac{N_t}{N_0} = 0.6102$

or $N_t = 0.6102 \times N_0$

$\therefore$ $N_t = 0.6102 \times 1$ μg

$= 0.6102$ μg

6. For the radioactive decay of A into B and C by two parallel paths



So, $\frac{-d[A]}{dt} = \lambda N$ ...(i)

$\frac{+d[B]}{dt} = \lambda_1 N$ ...(ii)

$\frac{+d[C]}{dt} = \lambda_2 N$ ...(iii)

where λ, λ_1 and λ_2 are radioactive decay constants, respectively, and N is the number of atoms of A at any given time.

Thus, $\frac{+d[A]}{dt} = \frac{d[B]}{dt} + \frac{d[C]}{dt}$

$\therefore$ $\lambda N = \lambda_1 N + \lambda_2 N$

$\therefore$ $\lambda = \lambda_1 + \lambda_2$

From Eqs. (ii) and (iii), we get

$$\frac{d[B]}{d[C]} = \frac{\lambda_1}{\lambda_2}$$

On integration, we get

$$\frac{[B]}{[C]} = \frac{\lambda_1}{\lambda_2}$$

For decay of Ac^{227} into Th^{227} and Fr^{223}, on the basis of given data

$$\frac{\lambda_1}{\lambda_2} = \frac{2.0}{98.0} \quad \text{...(iv)}$$

and $\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{22} = 0.0315 \text{ year}^{-1}$

So, $0.0315 = \lambda_1 + \lambda_2$ ...(v)

On solving Eqs. (iv) and (v), we get

$\lambda_1 = 6.3 \times 10^{-4}$ year^{-1} and $\lambda_2 = 0.03087$ year^{-1}

7. $_7N^{14} + {_2He^4} \longrightarrow \left[\underset{\text{unstable}}{_9F^{18}}\right] \longrightarrow {_8O^{17}} + {_1H^1}$

8. Let time = t year

$$_{92}U^{238} = 1.667 \text{ g} = \frac{1.667}{238} \text{ mol}$$

$$_{82}Pb^{206} = 0.277 \text{ g} = \frac{0.277}{206} \text{ mol}$$

$\because$ All the lead have come from decay of U.

$\therefore$ Mole of Pb formed $= \frac{0.277}{206}$

Mole of U decayed $= \frac{0.277}{206}$

$\therefore$ Total mole of uranium before decay,

$$N_0 = \frac{1.667}{238} + \frac{0.277}{206}$$

Also, N for $U^{238} = \frac{1.667}{238}$

For U^{238}, $t = \frac{2.303}{\lambda} \log_{10} \frac{N_0}{N}$

$$= \frac{2.303 \times 4.51 \times 10^9}{0.693} \log_{10} \frac{\frac{1.667}{238} + \frac{0.277}{206}}{\frac{1.667}{238}}$$

$= 1.143 \times 10^9$ years

9. Let x α- and y β-particles be given out during the change.

$$_{92}U^{238} \longrightarrow {_{82}Pb^{206}} + x\,{_2He^4} + y\,{_{-1}e^0}$$

Equating mass number on both sides.

$238 = 206 + 4x + y \times 0$

$\therefore$ $x = 8$

Equating atomic number on both sides,

$92 = 82 + 2x + y(-1) = 82 + 2 \times 8 + y(-1)$

$\therefore$ $y = 6$

$\therefore$ Number of α-particles = 8

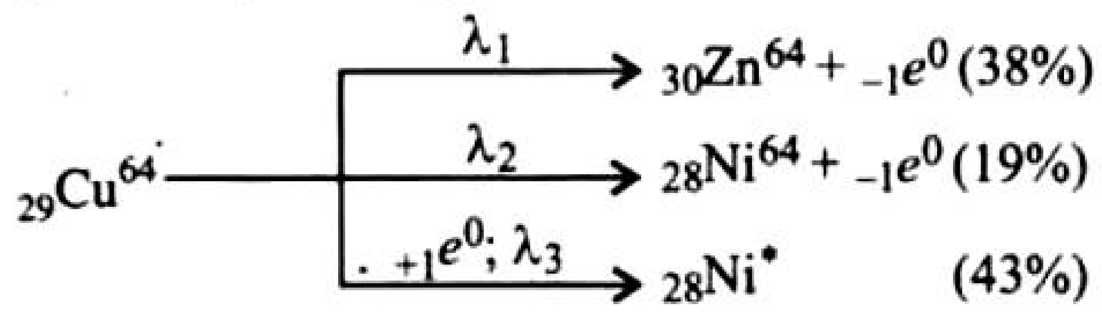
Number of β-particles = 6

10. The nuclear reactions are:

$$_{29}Cu^{64} \longrightarrow {_{30}Zn^{64}} + {_{-1}e^0} \; ({_{-1}\beta^0})$$

$$_{29}Cu^{64} \longrightarrow {_{28}Ni^{64}} + {_{+1}e^0} \; ({_{+1}\beta^0})$$

$$_{29}Cu^{64} + _{-1}e^0 \longrightarrow {}_{28}Ni^{64}$$



Given, $\lambda_{avg} = \frac{0.693}{12.8} hr^{-1}$

$$\therefore \quad \lambda_1 + \lambda_2 + \lambda_3 = \lambda_{avg} = \frac{0.693}{12.8} = 5.41 \times 10^{-2}\ hr^{-1} \quad ...(i)$$

Also for parallel path decay

λ_1 = Fractional yield of $_{30}Zn^{64} \times \lambda_{avg}$

λ_2 = Fractional yield of $_{28}Ni^{64} \times \lambda_{avg}$

λ_3 = Fractional yield of $_{28}Ni^{64*} \times \lambda_{avg}$

$$\frac{\lambda_1}{\lambda_2} = \frac{38}{19} \quad ...(ii)$$

and $$\frac{\lambda_1}{\lambda_3} = \frac{38}{43} \quad ...(iii)$$

From Eqs. (i), (ii), and (iii), $\lambda_1 = 2.056 \times 10^{-2}\ hr^{-1}$

$\lambda_2 = 1.028 \times 10^{-2}\ hr^{-1}$; $\lambda_3 = 2.327 \times 10^{-2}\ hr^{-1}$

$$t_{1/2} \text{ for } \beta^{\ominus}\text{-emission} = \frac{0.693}{2.056 \times 10^{-2}} = 33.70\ hr$$

$$t_{1/2} \text{ for } \beta^{\oplus}\text{-emission} = \frac{0.693}{1.028 \times 10^{-2}} = 67.41\ hr$$

$$t_{1/2} \text{ for electron capture} = \frac{0.693}{2.327 \times 10^{-2}} = 29.78\ hr$$

11. Nuclear reaction is

$$_{90}Th^{234} \longrightarrow 7\ _2He^4 + 6\ _{-1}e^0 + _ZX^A$$

Equating atomic number on both sides

$90 = 14 + 6 \times (-1) + Z$

$\therefore \quad Z = 82$

Equating mass number on both sides

$234 = 7 \times 4 + 6 \times 0 + A$

$\therefore \quad A = 206$

Thus, element with atomic number 82 and mass number 206 is $_{82}Pb^{206}$.

12. $_{92}U^{238} \longrightarrow {}_{82}Pb^{214} + x\ _2He^4 + y\ _{-1}e^0$

Equating atomic number on both sides

$238 = 214 + x \times 4 + y \times 0$

$\therefore \quad x = 6$

Hence, 6 α-particles are emitted.

Equating atomic number on both sides

$92 = 82 + 6 \times 2 + y(-1)$

$\therefore \quad y = 2$

Hence, 2 β-particles are emitted.

Therefore, total 8 particles (6α, 2β) are emitted.

13. $_{92}U^{235} \longrightarrow {}_{54}Xe^{142} + _{38}Sr^{90} + x\ _0n^1$

Equating atomic number on both sides

$235 = 142 + 90 + x$

$\therefore \quad x = 3$

Hence, 3 neutrons are emitted.