3
Chapter

NUCLEAR CHEMISTRY

A SINGLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

1. Based on magic numbers, which nuclide is the most stable?
(a) Ni^{59} (b) V^{51}
(c) C^{12} (d) O^{16}

2. Which of the following nuclides is the least stable ?
(a) Zr^{91} (b) Co^{58}
(c) C^{13} (d) Ne^{20}

3. $_{13}Al^{27}$ is a stable isotope. $_{13}Al^{29}$ is expected to disintegrate by :
(a) α-emission (b) β-emission
(c) positron emission (d) proton emission

4. In beta decay of an element, electrons are emitted from ..... and the effect involves the change of ......
(a) valence shell, proton to neutron
(b) K-shell, neutron to proton
(c) nucleus, neutron to proton
(d) nucleus, electron to positron

5. How much energy in MeV is produced by alpha (4.0026 u) decay of each U^{235} atom (235.0439 u) to Th^{231} atom (231.0363 u)?
(a) 4.7 MeV (b) 46.6 MeV
(c) 0.47 MeV (d) none of these

6. A nuclide has *n*/*p* ratio lying below and to the right of belt of stability. The nuclide is likely to decay by:
(a) α-emission
(b) β-emission
(c) only positron emission
(d) either positron emission or electron capture

7. *n*/*p* ratio of an element with atomic number greater than 83 falls in the zone of instability. The element will undergo
(a) α-decay (b) β-decay
(c) β^+ -decay (d) no decay

8. Which could be the member of uranium series ?
(a) U^{236} (b) At^{217}
(c) Po^{216} (d) none of these

9. Proton bombardment of Th^{230} followed by emission of two alpha particles produces
(a) Rn^{232} (b) Fr^{223}
(c) Ra^{223} (d) Fr^{222}

10. By successive radioactive decays, $_{92}U^{235}$ is converted into $_{82}Pb^{207}$. The total number of α and β- particles emitted will be
(a) 7α and 4β (b) 16α and 14β
(c) 12α and 13β (d) 19α and 3β

11. In the radioactive decay

$${}_{Z}A^{A} \rightarrow {}_{Z-2}B^{A-4} \rightarrow {}_{Z-1}C^{A-4} \rightarrow {}_{Z}A^{A-4}$$

the sequence of radiation emitted is
(a) α, β, γ (b) α, β, β
(c) β, α, α (d) α, γ, γ

12. Which of the following nuclides is positron emitter ?
(a) H^3 (b) He^6
(c) B^{12} (d) N^{13}

13. Gamma ray emission during radioactive decay is due to the
(a) fall of excited electron to the lower energy state
(b) return of excited nucleus, left over by α- and β- emission, into the lower energy state
(c) too large *n*/*p* ratio
(d) too small *n*/*p* ratio

MARK YOUR RESPONSE					
	1. (a)(b)(c)(d)	2. (a)(b)(c)(d)	3. (a)(b)(c)(d)	4. (a)(b)(c)(d)	5. (a)(b)(c)(d)
	6. (a)(b)(c)(d)	7. (a)(b)(c)(d)	8. (a)(b)(c)(d)	9. (a)(b)(c)(d)	10. (a)(b)(c)(d)
	11. (a)(b)(c)(d)	12. (a)(b)(c)(d)	13. (a)(b)(c)(d)		

14. If t is the time required for a radioactive substance to reduce to one third of its initial amount, what fraction would be left over after $0.5\, t$

(a) $\frac{1}{2}$ (b) $\frac{1}{\sqrt{2}}$

(c) $\frac{1}{\sqrt{3}}$ (d) $\sqrt{2/3}$

15. Out of a radioactive sample 90% is found after one day. What percent of the original sample can be found after 2 days?

(a) 64% (b) 72%

(c) 81% (d) 45%

16. If *D/P* is the ratio of the mole atoms of daughter and its parent radioactive element in a rock specimen, the age of the rock is given by

(a) $t = \frac{2.303}{\lambda}\log(1+\frac{P}{D})$ (b) $t = \frac{2.303}{\lambda}\log\frac{D}{P}$

(c) $t = \frac{2.303}{\lambda}\log\left(1+\frac{D}{P}\right)$ (d) none of these

17. A sample of uranium rock from moon contains equimolar amounts of U^{238} and Pb^{206}. The age of the rock will be ($t_{1/2}$ for $U^{238} = 4.5 \times 10^9$ yrs)

(a) 4.5×10^9 yrs. (b) 9.0×10^9 yrs.

(c) 13.5×10^9 yrs. (d) 2.25×10^9 yrs.

18. A radioactive mixture containing a short lived species *A* and a long lived species *B*, both emitting α-particles, at a given instant emits 10000 α-particles per minute. After 10 minutes the activity declines to 7000 particles per minute. If half lives of *A* and *B* are 10 minutes and 100 hours respectively, the ratio of activities of *A* and *B* in the initial sample is

(a) 3 : 7 (b) 4 : 6

(c) 6 : 4 (d) none of these

19. If 80% of a radioactive element undergoing decay is left over after a certain period of time t from the start, how many such periods should elapse from the start for the 50% of the element to be left over?

(a) 4 (b) 6

(c) 5 (d) 3

20. The radioactive decay, ${}_{83}Bi^{211} \rightarrow {}_{81}Tl^{207}$, takes place in 10 L closed container at 0ºC. Half-life of ${}_{83}Bi^{211}$ is 2.15 min. Starting with 1 mole of ${}_{83}Bi^{211}$, the pressure developed in the container after 4.30min. will be

(a) 16.8 atm (b) 22.4 atm

(c) 2.24 atm (d) 1.68 atm

21. The least stable radioactive isotope of an element has the largest

(a) half-life (b) atomic number

(c) decay constant (d) mass number

22. A radioactive element having decay constant to be 2.31×10^{-3} per day is reduced to 25% of its initial amount in a period of

(a) 300 days (b) 600 days

(c) 150 days (d) 450 days

23. Of the following pairs of nuclides : (i) ${}_{20}Ca^{40}$ or ${}_{20}Ca^{42}$ (ii) ${}_{15}P^{31}$ or ${}_{15}P^{32}$ (iii) ${}_{30}Zn^{63}$ or ${}_{30}Zn^{64}$

which are the most abundant isotopes in the natural sources?

(a) ${}_{20}Ca^{40}$, ${}_{15}P^{32}$, ${}_{30}Zn^{63}$ (b) ${}_{20}Ca^{42}$, ${}_{15}P^{31}$, ${}_{30}Zn^{64}$

(c) ${}_{20}Ca^{40}$, ${}_{15}P^{31}$, ${}_{30}Zn^{64}$ (d) ${}_{20}Ca^{40}$, ${}_{15}P^{31}$, ${}_{30}Zn^{63}$

24. Which can not be a member of actinium series, which begins with U^{235}

(a) Ac^{237} (b) Ra^{223}

(c) Pb^{211} (d) Ra^{221}

25. A radioactive isotope *X* with half-life of 1.37×10^9 yrs decays to *Y* which is stable. A sample of rock was found to contain both the elements *X* and *Y* in the mole ratio of 1 : 7. What is the age of the rock ?

(a) 1.96×10^8 yrs. (b) 3.85×10^9 yrs.

(c) 4.11×10^9 yrs. (d) 9.06×10^9 yrs.

26. A radioactive element *A* of decay constant λ_A decays into another radioactive element *B* of decay constant λ_B. If start is made with No active nuclei of *A* and the time of maximum activity of daughter element *B* is $\frac{2\ell_n 2}{\lambda_A}$, the maximum number of active nuclei of *B* is

(a) $\frac{\lambda_A}{\lambda_B} N_0\, e^{-\lambda_B t}$ (b) $\frac{\lambda_A N_0}{4\lambda_B}$

(c) N_0 (d) none of these

MARK YOUR RESPONSE					
	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ
	19. ⓐⓑⓒⓓ	20. ⓐⓑⓒⓓ	21. ⓐⓑⓒⓓ	22. ⓐⓑⓒⓓ	23. ⓐⓑⓒⓓ
	24. ⓐⓑⓒⓓ	25. ⓐⓑⓒⓓ	26. ⓐⓑⓒⓓ		

27. Lead is always present in a uranium ore due to radioactive decay of U^{238} ($t_{1/2} = 4.5 \times 10^9$ yrs.) to Pb^{206} (end product). In a uranium mineral, U^{238} to Pb^{206} mole ratio was found to be 1 : 3. Hence, the age of the mineral is

(a) 2.25×10^9 yrs. (b) 1.5×10^9 yrs.
(c) 9.0×10^9 yrs. (d) 1.25×10^9 yrs.

28. The missing particle in the nuclear reaction,

$_{92}U^{235} + {_0}n^1 \rightarrow {_{56}}Ba^{146} + 3\,{_0}n^1$ is :

(a) $_{35}Br^{86}$ (b) $_{36}Kr^{87}$
(c) $_{35}Br^{89}$ (d) $_{32}Ge^{87}$

29. Half-life of radon is 6.931 days. After how many days one-tenth of radon sample remains behind ?

(a) 23 d (b) 2.3 d
(c) 230 d (d) 0.23 d

30. In some fission process, the mass number of fission fragments are 144 and 90 respectively. If the K.E. of heavy fragment is 70 MeV, the total fission energy is

(a) 200 MeV (b) 182 MeV
(c) 190 MeV (d) 170 MeV

31. During the fission of U^{235}, energy of the order of 180 MeV is generated per nucleus fissioned. The amount of enregy released by the fission of 0.235 g of U-235 is :

(a) 1.73×10^7 k J (b) 1.08×10^{25} k J
(c) 1.73×10^{15} k J (d) 1.08×10^7 k J

32. A radioactive isotope *A* decays into another isotope *B* which has half-life equal to half of that of *A*. If a sample consists initially of atoms of *A* only, then net activity of the sample

(a) increases with time (b) decreases with time
(c) remains constant (d) none of these

33. Which of the following processes leads to the emission of *X*-ray ?

(a) α-decay (b) β-decay
(c) positron decay (d) electron capture

34. A radioactive sample has an initial activity of 64 dpm. 15 minutes later it has an activity of 32 dpm. What would be number of atoms in a sample having an activity of 6.93 dpm.

(a) 300 (b) 150
(c) 450 (d) 200

35. Two radioactive nuclides *A* and *B* have half-lives in the ratio 2 : 3. Starting with a sample containing the two nuclides in equimolar amounts, what would be the mole ratio $n_A : n_B$ after a time interval which is three times of the half life of *A*?

(a) 1 : 2 (b) 2 : 1
(c) 1 : 3 (d) 1 : 4

36. The fraction of a radioactive element that decays in time *t*, is given by (λ = decay constant)

(a) $e^{-\lambda t}$ (b) $1 - e^{-\lambda t}$
(c) $1/e^{-\lambda t}$ (d) $1/1 - e^{-\lambda t}$

37. The activity per ml of a solution of radioactive substance is *x*. How much water be added to 200 ml of this solution so that the activity falls to *x*/20 per ml after 4 half-lives ?

(a) 100 ml (b) 150 ml
(c) 80 ml (d) 50 ml

38. Two radioactive element *A* and *B* have half-lives in the ratio of 1 : 2. If half-life of *A* is 2 days, what will be the mole ratio of *A* to *B* after 12 days in a sample initially containing 1 mole of each?

(a) 1 : 2 (b) 1 : 4
(c) 1 : 6 (d) 1 : 8

39. Two radioactive nuclides *X* and *Y* have half-lives of 30 and 10 minutes respectively. A sample contains the number of nuclides of *Y* to be 4 times that of *X*. How much time should elapse so that the number of nuclides of *X* and *Y* become equal ?

(a) 60 min. (b) 30 min.
(c) 20 min. (d) 15 min.

40. A piece of wood from an archaeological source shows C-14 activity which is 25% of the activity found in a fresh wood. The age of the sample is ($t_{1/2}$ for C-14 = 5770 yrs.)

(a) 1448 yrs. (b) 2885 yrs.
(c) 5770 yrs. (d) 11540 yrs.

41. A compound tagged with radioactive tritium, $_1H^3$ has an activity of 3.2×10^8 cpm. How much time would it take for the acitivity to decline to 2×10^7 cpm ($t_{1/2}$ of $_1H^3$ = 12.26 yrs.)

(a) 24.52 yrs. (b) 36.78 yrs.
(c) 49.04 yrs. (d) 98.04 yrs.

MARK YOUR RESPONSE					
	27. ⓐⓑⓒⓓ	28. ⓐⓑⓒⓓ	29. ⓐⓑⓒⓓ	30. ⓐⓑⓒⓓ	31. ⓐⓑⓒⓓ
	32. ⓐⓑⓒⓓ	33. ⓐⓑⓒⓓ	34. ⓐⓑⓒⓓ	35. ⓐⓑⓒⓓ	36. ⓐⓑⓒⓓ
	37. ⓐⓑⓒⓓ	38. ⓐⓑⓒⓓ	39. ⓐⓑⓒⓓ	40. ⓐⓑⓒⓓ	41. ⓐⓑⓒⓓ

42. The half-life of a radioactive element is 30 min. The time interval between the stages of 33.3% and 67.7% decay will be

(a) 60 min. (b) 90 min.
(c) 30 min. (d) 45 min.

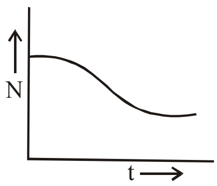
43. A sample contains two radioactive substances *A* and *B* in the ratio of 4 : 1. If their half-lives are 12 and 16 hours respectively, then after two days what will be the ratio of *A* and *B*?

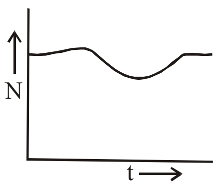
(a) 1 : 1 (b) 2 : 1
(c) 1 : 2 (d) 1 : 4

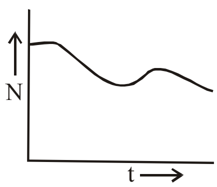
44. A radioactive element has half-life of 2 minutes and nuclei to be *N*. If one of the nuclei decays just now, the next will decay

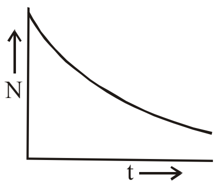
(a) after 1 minute (b) after $\frac{0.693}{\lambda}$ minutes
(c) after $\frac{2}{N}$ minutes (d) after any time

45. A sample consists of two radioactive elements having equal number of nuclei initially. The average life of one element is T and that of the other is $5\,T$. The decay product in both cases are stable. Which of the following curve will represent the variation of total number of radioactive nuclei with time?

(a) 

(b) 

(c) 

(d) 

46. Two radioactive elements *X* and *Y* have decay constants λ and 10λ respectively. If decay begins with the same number of atoms of them, the ratio of atoms of *X* to those of *Y* after time $\frac{1}{9\lambda}$ will be

(a) e (b) e^{-1}
(c) e^2 (d) e^{-2}

47. Half-life time of radioactive element *X* is the same as the mean life time of another radioactive element *Y*. Initially both of them have same number of atoms. Then

(a) *X* and *Y* have the same decay rate initially
(b) *X* and *Y* decay at the same rate always
(c) *Y* will decay at faster rate than *X*
(d) *X* will decay at faster rate than *Y*

48. A radioactive material decays by simultaneous emission of two particles with half-lives 1620 and 810 years. The time after which one- fourth of the material remains, is

(a) 1080 years (b) 2430 years
(c) 3240 years (d) 4860 years

49. Activity of a radioactive substance is A_1 at time t_1 and A_2 at time t_2 $(t_2 > t_1)$. The activity ratio $\frac{A_2}{A_1}$ is (λ = decay constant)

(a) $10^{\lambda(t_2-t_1)}$ (b) $e^{\lambda(t_2-t_1)}$
(c) $e^{\frac{(t_2-t_1)}{\lambda}}$ (d) $e^{\lambda(t_1-t_2)}$

50. A piece of wood was burned and 7.32 g of CO_2 was collected. The total radioactivity in CO_2 was 7.6 dpm. How old was the wood sample? Given $t_{1/2}$ of C-14 = 5730 years, specific activity of carbon obtained from a fresh wood sample is 15.2 dpm.

(a) 5730 years (b) 11460 years
(c) 22920 years (d) None of these

51. A 0.20 mL sample of solution containing 1.0×10^{-7} Ci of $_1H^3$ is injected into the blood stream of an animal. After sufficient time of circulatory equilibrium to be established, 0.10 ml blood is found to have an activity of 22.2 dmp. Calculate the blood volume of the animal

(a) 1.0 L (b) 1.2 L
(c) 1.5 L (d) 2.0 L

52. A sample of river water was found to contain 8×10^{-18} tritium atoms, $_1H^3$, per atom of ordinary hydrogen. Tritium decays with a half-life of 12.3 years. What will be the ratio of tritium to normal hydrogen atoms in the sample after 49.2 years

(a) 2.0×10^{-18} (b) 1.0×10^{-18}
(c) 5.0×10^{-18} (d) 5.0×10^{-19}

MARK YOUR RESPONSE					
	42. ⓐⓑⓒⓓ	43. ⓐⓑⓒⓓ	44. ⓐⓑⓒⓓ	45. ⓐⓑⓒⓓ	46. ⓐⓑⓒⓓ
	47. ⓐⓑⓒⓓ	48. ⓐⓑⓒⓓ	49. ⓐⓑⓒⓓ	50. ⓐⓑⓒⓓ	51. ⓐⓑⓒⓓ
	52. ⓐⓑⓒⓓ				

53. Which of the following nuclides is least likely to be stable?

(a) ${}_{20}C^{40}$ (b) ${}_{13}Al^{30}$
(c) ${}_{50}Sn^{119}$ (d) ${}_{25}Mn^{55}$

54. Which of the following is incorrect for **nuclear isomers**?

(a) They have same mass number
(b) They have same atomic number
(c) They are in same energy state
(d) They are atoms of the same element

55. In **isomeric transition**

(a) There is small change in charge of nuclei
(b) There is small change in mass of nuclei.
(c) There is no change in charge and mass of nuclei
(d) These is a change both in charge and mass of nuclei.

56. Nuclear isomerism is due to

(a) difference in arrangement of nucleons but no difference in energy of nucleons
(b) difference in arrangement of protons but no difference in energy of nucleons
(c) difference in arrangement of neutrons but no difference in energy of nucleons
(d) difference in energy of nucleons and difference in arrangement of nucleons.

57. A pair of nuclear isomers occurring in nature is uranium X_2 and uranium Z_1, which are found in uranium decay series.

(a) both these isomers have same mass number but different atomic numbers
(b) both these isomers have same atomic number but different mass numbers
(c) both these have same atomic number and same mass number
(d) None of the above is correct.

58. For a spallation reaction, which is **incorrect** statement?

(a) The nucleus produced in such a reaction has atomic number 10-20 units less than the parent nucleus
(b) The reaction is self sustaining
(c) The change in mass for a spallation reaction is not so great as that in a fission reaction.
(d) spallation reaction is a nuclear reaction

59. In **endoergic reaction**, the total mass of products

(a) is more than that of reactants
(b) is less than that of reactants
(c) sometimes more and sometimes less than the mass of the reactants.
(d) is same as the masses of reactants

60. When a β-particle is emitted, the atomic number of daughter element is one unit more as compared to that of parent element. This increase in atomic number is due to

(a) addition of a proton to the nucleus.
(b) removal of an electron from the nucleus
(c) decay of neutron present in the nucleus
(d) any one of the above

61. During emission of β-ray, a neutron present in the nucleus decays to produce

(a) a proton
(b) an electron
(c) an electron and a proton
(d) an electron, proton and a neutrino

62. Select the correct statement

(a) One of the natural radioactivity series discovered is uranium-238 series
(b) Mean or average life of a radioactive substances (λ’) is given by the relation

$$\lambda' = \frac{1}{\lambda} \quad (\lambda = \text{disintegration constant})$$

(c) The U-238 disintegration series involves 14 steps
(d) All the above are correct.

63. The U-238 disintegration series

(a) is also called $(4n + 1)$ series
(b) involves 8 steps of α-emission
(c) is also called $(4n + 3)$ series
(d) all the above are correct

64. Which of the following is **incorrect** about radioactive equilibrium

(a) At radioactive equilibrium all the radio elements disintegrate at the same rate
(b) Radioactive equilibrium like chemical equilibrium is reversible
(c) The shorter the half life period, the more easily is equilibrium state attained.
(d) At equilibrium, the various constituents of the system will be present in the ratio of their half -lives.

MARK YOUR RESPONSE					
	53. ⓐⓑⓒⓓ	54. ⓐⓑⓒⓓ	55. ⓐⓑⓒⓓ	56. ⓐⓑⓒⓓ	57. ⓐⓑⓒⓓ
	58. ⓐⓑⓒⓓ	59. ⓐⓑⓒⓓ	60. ⓐⓑⓒⓓ	61. ⓐⓑⓒⓓ	62. ⓐⓑⓒⓓ
	63. ⓐⓑⓒⓓ	64. ⓐⓑⓒⓓ			

65. Boron is most commonly used control matterial in nuclear reactors. It is generally incorporated in a metal e.g. in stainless steel to form boron steel. The carbide (B_4C) is frequently dispersed in a metal e.g. in aluminium, when the product is called

(a) Alumino-boron (b) Boral

(c) Alubor (d) None of these

66. **Thermal reactors** are most commonly used reactors in different countries. Indian reactor **Apsara** belongs to this class of reactors.

Select the **incorrect** statement about **Apsara**.

(a) It is a swimming pool reactor

(b) It is situated at Trombay

(c) It was named **Apsara** on the name of **sea mermaid** which is half under sea and half outside

(d) None of the above is correct

MARK YOUR RESPONSE	65. ⓐⓑⓒⓓ	66. ⓐⓑⓒⓓ			

B COMPREHENSION TYPE

This section contains groups of questions. Each group is followed by some multiple choice questions based on a paragraph. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct.

PASSAGE-1

Ordinary chemical reactions consist simply of rearrangement of the electrons in atoms and molecules. In these changes, the atomic nuclei involved are not affected. In the phenomenon of radioactive disintegration, both nuclei and electrons can be involved. A reaction of this kind is referred to as a nuclear reaction. One method of producing nuclear alteration involves the bombardment of atomic nuclei with various kinds of high speed particles.

The possibility of artificial transmutation was first suggested when it was discovered that different kinds of atoms are composed of the same fundamental units; protons, electrons and neutrons. Essentially, the problem is how the number of each of these types of particles could be changed. Rutherford first suggested that alpha particles, which could be easily obtained from radium, could be used. He thought that a few of the particles might make direct hits and either combine with the nuclei or break them up. His theory was proven when he used these particles to transmute ^{14}N to ^{17}O and the chemical community was shocked. Since then, protons (p), photons (γ - rays in particular), neutrons (n), electrons ($_{-1}e^0$) and positrons ($_1e^0$) have been used in these types of reactions.

1. What is the nuclear reaction for the transmutation of ^{14}N to ^{17}O ?

(a) $^{14}_{7}N \;\; ^{4}_{2}He \longrightarrow n \;\; ^{17}_{8}O$

(b) $^{14}_{7}N \;\; ^{4}_{2}He \longrightarrow p \;\; ^{17}_{8}O$

(c) $^{14}_{7}N \;\; ^{4}_{2}He \longrightarrow \; ^{0}_{-1}e \;\; ^{17}_{8}O$

(d) $^{14}_{7}N \;\; ^{4}_{2}He \longrightarrow \; ^{0}_{1}e \;\; ^{17}_{8}O$

2. The larger the bombarding particle and the greater its charge, the more difficult it is to use in artificial transmutation. Which of the following represents the order of particlts in terms of increasing ability to be used in these type of reactions given that charge is the more important factor?

(a) $n < p < e < \alpha$

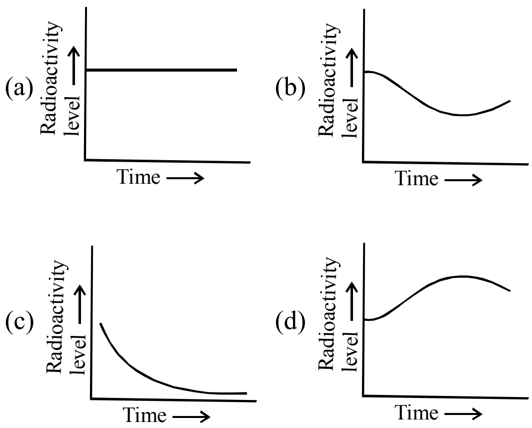
(b) n e p α

(c) α e p n

(d) α p e n

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ			

3. A radioactive form of phosphorus undergoes υ-decay. What would the radioactivity level (R) versus time graph for the decay process look like FIGURE ?



4. How do you suppose a positron will react in an electric field ?

(a) It would retain its original flight path

(b) It would be attracted to the positive plate

(c) It would be attracted to the negative plate

(d) It would be attracted to the plate with the greater charge density

5. Given that a particular β-particle has a kinetic energy of 2.275×10^{-5} J, what is the velocity of this particle? Mass of an electron 9.1×10^{-31} kg ?

(a) $1.0\times10^{8}\,ms^{-1}$ (b) $2.5\times10^{7}\,ms^{-1}$

(c) $7.1\times10^{7}\,ms^{-1}$ (d) $1.4\times10^{7}\,ms^{-1}$

PASSAGE-2

The size of the nucleus of an atom is very small since its radius is nearly 10^{-15} m. The nucleus comprised mainly of protons and neutrons is quite offen stable despite the very strong repulsive forces between the protons. The neutrons and protons, collectively called **nucleons**, are held together by very strong and short range forces, called nuclear forces. Nuclear forces are nearly 10^{21} times stronger than electrostatic forces. These forces come into play by very rapid exchange of nuclear particles, called π-mesons.

$$\text{proton} \rightleftharpoons \text{neutron} + \pi^{+}$$

$$\text{proton} + \pi^{-} \rightleftharpoons \text{neutron}$$

The binding forces between unlike nucleons (*p* and *n)* are explained by the oscillation of a charged pi meson (π^+ and π^-). Binding forces between like nucleons (*p-p* or *n-n*) result from the exchange of neutral mesons (π°).

The stability of nucleus very much depends on the ratio of neutrons to protons (*n/p* ratio). This ratio for stable nuclei is close to unity for lighter elements whereas for heavier elements it ranges between 1 – 1.5. If *n/p* ratio is either too high or too low, the nucleus of such elements are expected to be unstable in nature. In order to acquire stability they emit α, β or some other particles and thus show the radioactivity.

In radioactive disintegration the daughter nuclei have different atomic number than the parent nuclei. The nature of emitted particle (α or β) depends on the *n/p* ratio of the parent nuclei and so also the atomic numbers of daughter nuclei. Thus, daughter nuclei find different position in the periodic table than those of parent elements.

6. Which of the following particles is most likely to be emitted by Na-24?

(a) ${}^{4}_{2}He$ (b) ${}^{1}_{1}H$

(c) ${}^{0}_{-1}e$ (d) ${}^{0}_{+1}e$

7. The particle which is most likely to be emitted by C-11 is

(a) ${}^{1}_{0}n$ (b) ${}^{1}_{1}H$

(c) ${}_{-1}e^{0}$ (d) ${}_{+1}e^{0}$

8. U-238 has the

(a) β-rays activity (b) α-rays activity

(c) positron activity (d) none of these

PASSAGE-3

Natural uranium contains two isotopes : ^{238}U and the much rarer ^{235}U. The latter is the isotope responsible of the vast release of energy during nuclear fission. The two major uses of ^{235}U are in nuclear reactors and in atomic bombs. Both of these processes rely on self–sustaining fission reactions.

MARK YOUR RESPONSE	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ
	8. ⓐⓑⓒⓓ				

The radioactive disintegration of ^{235}U involves, as a first step, the incorporation of a slow moving neutron into its nucleus. All of the neutrons released during nuclear fission are capable of splitting another ^{235}U nucleus. Each reaction produces three neutrons and provided that the chain can build up rapidly enough, there is an enormous release of energy and this is the basis of the action of the atomic bomb. This will only occur if the ^{235}U sample present is larger than a certain mass known as the *critical size.* In the atomic bomb, two pieces of pure ^{235}U or ^{239}Pu each below the critical size are brought together to form one piece larger than the critical size and this leads to the explosion.

In the nuclear reactor, the *atomic pile* consists of rods of uranium inserted into channels surrounded by blocks of graphite. The temperature of the pile can be controlled by the use of movable boron or cadmium rods. The heat generated during the fission process is removed by a stream of carbon dioxide. The hot gas is then used to produce steam which drives a turbine and so produces electrical energy.

9. Why must the uranium rods be stored well apart before use in the reactor ?

(a) Because a fusion reaction would begin while in storage.
(b) Because an explosion could occur.
(c) Because they are then easier to transport
(d) Because conversion of ^{235}U to non-fissionable ^{238}U would occur.

10. In an atomic bomb, the chain reaction depends on

(a) all three neutrons produced from a ^{235}U nucleus splitting other ^{235}U
(b) at least four neutrons produced from a ^{235}U nucleus splitting other nuclei
(c) at least two neutrons produced from a ^{235}U nucleus splitting another ^{235}U nucleus
(d) none of the above

11. Given the following reactions, identify X.

$${}_0^1n + {}_{92}^{238}U \longrightarrow {}^{239}U + X$$

$${}_{92}^{239}U \longrightarrow {}_{93}^{239}Np + {}_{-1}^{0}e$$

$${}_{93}^{239}Np \longrightarrow {}_{94}^{239}Pu + {}_{-1}^{0}e$$

(a) positron (b) neutron
(c) electron (d) proton

12. The Dounreay Nuclear Power Station has been in operation for quite some time. Over the last six years, they have turned out a total of two megawatt-years of energy. Assuming that operation were continuous over the six year period at a constant rate, what was its power in watts?

(a) 3.3×10^5 W (b) 6.6×10^5 W
(c) 3.3×10^2 W (d) 6.6×10^2 W

13. Nuclear reactors are usually surrounded by lead and concrete. Which of the following is this safety precaution particularly for?

(a) α -particle (b) β -particle
(c) γ -rays (d) proton

PASSAGE-4

Nuclear binding energy may be defined as the energy released when the given number of protons and neutrons coalesce to form its nucleus. In other words, it is the energy required to disrupt its nucleus into the constituent neutrons and protons. Thus

Mass defect (Δm) = {[Neutron mass + Proton mass + Electron mass] – [Actual mass of atom]} a.m.u.

Binding energy = Mass defect × 931.5 MeV.
(in amu)

and binding energy per nucleon $= \dfrac{\text{Binding energy}}{\text{Mass number}}$

14. What is the binding energy for ${}_2^4He$. The mass of ${}_2He^4$ from mass spectrograph measurement is 4.00390 amu. [Given mass of proton, electron and neutron are 1.007277 amu, 0.0005486 amu and 1.008665 amu respectively]

(a) 270.9 MeV (b) 27.09 MeV
(c) 2.709 MeV (d) None of these

15. What is the binding energy of last proton in ${}_6C^{12}$? [Given masses, ${}_5B^{11}$ = 11.009305 amu, ${}_6C^{11}$ = 11.010433 amu, proton = 1.0078 amu and neutron = 1.0087 amu]

(a) 12 MeV (b) 4 MeV
(c) 16 MeV (d) 20 MeV

16. What is the binding energy of last neutron in ${}_6C^{12}$? [Given, masses ${}_5B^{11}$ = 11.009305 amu, ${}_6C^{11}$ = 11.010433 amu, proton = 1.0078 amu and neutron = 1.0087 amu]

(a) 16.0 MeV (b) 18.75 MeV
(c) 20.25 MeV (d) None of these

MARK YOUR RESPONSE					
	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ
	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ		

PASSAGE-5

The group displacement law given by Soddy and Fazan for emission of α and β- particles may be stated as follows.

The emission of α-particle by an element results in the formation of new element which lies two places left to the parent element, and the emission of β-particle results in the formation of a new element which lies one place to the right of the parent element in the periodic table.

It may be noted that emission of a β-particle results in production of an isobar while emission of α- particle followed by emission of two β-particles produces an isotope of the parent element.

This can be illustrated by an example given below :

$${}_{84}Po^{215} \xrightarrow{-\alpha} {}_{82}Pb^{211} \xrightarrow{-\beta} {}_{83}Bi^{211} \xrightarrow{-\beta} {}_{84}Po^{211}$$

Group: 16 14 15 16

Here ${}_{84}Po^{215}$ and ${}_{84}Po^{211}$ are isotopes, while ${}_{82}Pb^{211}$ and ${}_{83}Bi^{211}$ are isobars.

17. ${}_{92}U^{235}$ and ${}_{90}Th^{231}$ are
(a) Isotopes (b) Isobars
(c) Isodiaphers (d) Isosters

18. HCl and F_2 are
(a) Isotopes (b) Isobars
(c) Isodiaphers (d) Isosters

19. ${}_{7}N^{17}$ and ${}_{8}O^{18}$ are
(a) Isotopes (b) Isobars
(c) Isotones (d) None of these

MARK YOUR RESPONSE	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ	19. ⓐⓑⓒⓓ		

C REASONING TYPE

In the following questions two Statement-1 (Assertion) and Statement-2 (Reason) are provided. Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONLY ONE is correct. Mark your responses from the following options:

(a) Both Statement-1 and Statement-2 are true and Statement-2 is the correct explanation of Statement-1.
(b) Both Statement-1 and Statement-2 are true and Statement-2 is not the correct explanation of Statement-1.
(c) Statement-1 is true but Statement-2 is false.
(d) Statement-1 is false but Statement-2 is true.

1. Statement-1 : ${}_{1}H^{1}$, ${}_{1}H^{2}$ and ${}_{1}H^{3}$ are isotopes of hydrogen.
Statement-2 : Nuclides of the same element of different mass numbers are called isotopes of that element.

2. Statement-1 : α-particles are fast moving electrons.
Statement-2 : α-particles are stopped by a few sheets of paper or a very thin metal foil.

3. Statement-1 : α-rays have greater ionizing power than β-rays.
Statement-2 : α-particles carry two unit positive charge while β-particles carry only one unit negative charge.

4. Statement-1 : The velocity of γ-radiations is larger than β-particles.
Statement-2 : γ-radiation cannot be stopped.

5. Statement-1 : Nuclear forces are called short range forces.
Statement-2 : Nuclear forces operate over very small distance i.e., 10^{-15} m or 1 fermi.

6. Statement-1 : Nucleons are held together due to their fast exchange into one-another through mesons.
Statement-2 : Mesons are massless and chargeless particles.

MARK YOUR RESPONSE	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ
	6. ⓐⓑⓒⓓ				

7. **Statement-1** : Radioactive heavy nuclei decay by a series of α- and / or β-emissions, to form a stable isotope of lead.

Statement-2 : Radioactivity is a a physical phenomenon.

8. **Statement-1** : For maximum stability N/P ratio must be equal to 1.

Statement-2 : Loss of α- and β-particles has no role in N/P ratio.

9. **Statement-1** : The neutrons are better initiators of nuclear reactions, than the protons, deutrons or α-particles of the same energy.

Statement-2 : Neutrons are uncharged particles and hence, they are not repelled by positively charged nucleus.

10. **Statement-1** : $_{92}U^{235} + {_0}n^1 \longrightarrow {_{56}}Ba^{140} + {_{36}}Ke^{93} + 3\,{_0}n^1$ is a nuclear fission reaction.

Statement-2 : Neutrons emitted do not react further.

11. **Statement-1** : Breeder reactor produces fissile $_{94}Pu^{239}$ from non-fissile uranium.

Statement-2 : A breeder reactor is one that produces more fissionable nuclei than it consumes.

12. **Statement-1** : Tracers are used to know the course of the reaction.

Statement-2 : Tracer is a small amount of a sample of radioisotope.

13. **Statement-1** : Nuclide $_{13}Al^{30}$ is less stable than $_{20}Ca^{40}$

Statement-2 : Nuclides having odd number of protons and neutrons are generally unstable.

14. **Statement-1** : Neutrons have proved to be specially effective in producing nuclear disintegration because of their neutral character.

Statement-2 : α-particles usually bring about two types of transmutations ejecting protons and neutrons.

15. **Statement-1** : The commonest process which results from neutron capture is **radioactive capture**.

Statement-2 : In radioactive capture compound nucleus formed emits one or more γ-ray photon.

16. **Statement-1** : Many light elements between boron and calcium give rise to artificial radioactivity on being bombarded by α-particles.

Statement-2 : In artificial radioactivity produced by means of α-particles, the yield is very low and the yield decreases as the energy of α-particles.

MARK YOUR RESPONSE					
	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ
	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ

D MULTIPLE CORRECT CHOICE TYPE

Each of these questions has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE OR MORE is/are correct.

1. Which of the following statement is/are correct?
(a) Upto mass number about 60, the combination of lighter nuclides leads to increase of binding energy and hence release of energy.
(b) Upto mass number 60, the combination of lighter nuclides leads to decrease of binding energy and hence expenditure of energy ?
(c) Above mass number about 60, the addition of extra nucleons to the nucleus requires expenditure of energy
(d) Fusion of lighter nuclides to give a heavier one as well as the disintegration of heavier nucleus into the lighter ones are exothermic processes.

2. A radioactive element *X* emits α-particle followed by 2 β-particles in the successive steps as :

$$X(3.8\text{ d}) \xrightarrow[-\alpha \text{ particle}]{\lambda_1} Y\ (3\text{ min}) \xrightarrow[-2\beta \text{ particles}]{\lambda_2} Z$$

which of the following statement(s) is/are correct ?
(a) decay constant $\lambda_1 > \lambda_2$
(b) Atomic number of *X* and *Z* are the same
(c) *Y* and *Z* are isobars
(d) the mass number of *Y* is greater than *X*

3. Which of the following is/are used as moderator in a nuclear reactor ?
(a) Graphite (b) Heavy water
(c) Cadmium metal (d) Pressurized water

MARK YOUR RESPONSE					
	1. ⓐⓑⓒⓓ	2. ⓐⓑⓒⓓ	3. ⓐⓑⓒⓓ		

4. A moderator in the nuclear reactor
(a) absorbs secondary electrons of the fission to maintain the neutron multiplication factor to unity
(b) slows down the neutrons from the fission process
(c) causes the kinetic energy of high speed neutrons of the fission to decrease
(d) regulates the excess neutrons produced in the fission.

5. Which of the nuclides are doubly magic ?
(a) O^{16} (b) Fe^{56}
(c) Pb^{208} (d) Ni^{60}

6. Which of the following nuclides are β-emitters ?
(a) He-6 (b) Be-8
(c) B-12 (d) H-3

7. Which of the following triad(s) consist of all the nuclides to be isotonic ?
(a) K-39, Ca-40, Sc-45 (b) B-12, C-13, N-14
(c) $Ge^{76}, As^{77}, Ga^{75}$ (d) Ar-40, K-40, Ca-40

8. In atomic reactor, cadmium rods are used to
(a) slow down the fission neutrons
(b) decrease the kinetic energy of secondary electrons of the fission
(c) absorb and regulate the secondary neutrons of the fission
(d) decrease the neutron multiplication factor.

9. Which of the following statements is/are correct ?
(a) Radioactive isotope C-14 is formed by the bombardment of N-14 in the upper atmosphere by cosmic ray neutrons.
(b) The rate of formation of C-14 exceeds the rate at which it decays
(c) All living things contain constant proportion of C-14 and hence constant activity per g of carbon
(d) After the death of animal or plant, incorporation of C-14 stops and activity decreases due to continuous decay of C-14 which permits the age determination of organic matter.

10. A radioactive element *X* has an atomic number of 100. It decays directly into an element *Y* which decays directly into an element *Z*. In both processes a charged particle is emitted. Point out the correct statement(s) of the following
(a) *Y* has an atomic number of 102
(b) *Y* has an atomic number of 101
(c) *Z* has an atomic number of 100
(d) *Z* has an atomic number of 99

11. In massive stars, where the temperature is many times the solar temperature, the fusion involves predominantly
(a) proton-proton cycle (b) proton-nitrogen cycle
(c) carbon-nitrogen cycle (d) proton-deutron cycle

12. Consider the emission of α-particle from uranium nucleus:

$${}_{92}U^{235} \longrightarrow {}_{90}Th^{231} + {}_{2}He^{4}$$

Shortage of 2 electrons in thorium is due to :
(a) conversion of electron to positron
(b) combination of electron with positron to evolve energy
(c) annihilation
(d) absorbtion of electrons in the nucleus

13. In the radioactive decay of ${}_{Z}X^{A}$, which of the following could be considered correct statements ?
(a) α-decay involves the decrease of both *A* and *Z* by 2.
(b) β-decay involves the increase of *Z* by one, *A* remaining constant
(c) K-electron capture results in the decrease of *Z* by one with no change in *A* and emission of γ-rays
(d) γ-ray emission is followed by the emission of α or β-particles

14. Select the factor(s) that have no affect on rate of disintegration.
(a) pressure (b) temperature
(c) magnetic field (d) electric field

15. Which of the following statement (s) is/are **not** correct?
(a) For treatment of thyroid cancer we use I-131.
(b) For treatment of cancer Co-59 is used.
(c) For treatment of leukema P-33 is commonly used
(d) The excessive use of radio therapy may be harmful and may cause cancer

16. Which is/are **not** used as fuels in a nuclear reactor?
(a) oxide of thorium (b) oxide of plutonium
(c) oxide of actinium (d) oxide of lanthanum

17. Which of the following is/are **not** used as moderator in nuclear reactor?
(a) graphite (b) cadmium
(c) water (d) neutrons

18. Select those which are β-emitters
(a) Be-8 (b) H-3
(c) B-12 (d) He-6

MARK YOUR RESPONSE					
	4. ⓐⓑⓒⓓ	5. ⓐⓑⓒⓓ	6. ⓐⓑⓒⓓ	7. ⓐⓑⓒⓓ	8. ⓐⓑⓒⓓ
	9. ⓐⓑⓒⓓ	10. ⓐⓑⓒⓓ	11. ⓐⓑⓒⓓ	12. ⓐⓑⓒⓓ	13. ⓐⓑⓒⓓ
	14. ⓐⓑⓒⓓ	15. ⓐⓑⓒⓓ	16. ⓐⓑⓒⓓ	17. ⓐⓑⓒⓓ	18. ⓐⓑⓒⓓ

E — MATRIX-MATCH TYPE

Each question contains statements given in two columns, which have to be matched. The statements in Column-I are labeled A, B, C and D, while the statements in Column-II are labelled p, q, r, s and t. Any given statement in Column -I can have correct matching with ONE OR MORE statement(s) in Column-II. The appropriate bubbles corresponding to the answers to these questions have to be darkened as illustrated in the following example:
If the correct matches are A–p, s and t; B–q and r; C–p and q; and D–s then the correct darkening of bubbles will look like the given.

	p	q	r	s	t
A	●	○	○	●	●
B	○	●	●	○	○
C	●	●	○	○	○
D	○	○	○	●	○

1. Match the nuclides listed in column II with the characteristics listed in column I :

	Column I		Column II
(A)	Most stable nuclide amongst C^{12}, O^{16}, Co^{58}, Ni^{59}	p.	Fe^{56}
(B)	Least stable nuclide amongst C^{13}, O^{16}, Co^{58}, Fe^{56}	q.	Bi^{209}
(C)	Doubly magic nuclides amongst Fe^{56}, Co^{58}, Ni^{59}, Bi^{209}	r.	O^{16}
(D)	End product of disintegration series of Np^{237}	s.	Co^{58}

2. Match the following :

	Column I Nuclides		Column II Activity
(A)	Na^{24}	p.	α-particle emission
(B)	C^{11}	q.	${}_{-1}e^{0}$ emission
(C)	U^{238}	r.	β-particle emission
(D)	H^{3}	s.	${}_{+1}e^{0}$ emission

3. Match the following :

	Column I Series		Column II Particles emitted
(A)	Thorium	p.	$8\alpha, 5\beta$
(B)	Neptunium	q.	$7\alpha, 4\beta$
(C)	Uranium	r.	$6\alpha, 4\beta$
(D)	Actinium	s.	$8\alpha, 6\beta$

4. Match the following nuclear reactions with the appropriate missing nuclide.

	Column I Reactions		Column II Missing nuclide
(A)	${}_{6}C^{12} + \text{.........} \longrightarrow {}_{5}B^{10} + {}_{2}He^{4}$	p.	${}_{0}n^{1}$
(B)	${}_{7}N^{14} + \text{.........} \longrightarrow {}_{8}O^{17} + {}_{1}H^{1}$	q.	${}_{1}H^{1}$
(C)	${}_{4}Be^{9} + {}_{2}He^{4} \longrightarrow {}_{6}C^{12} + \text{.........}$	r.	${}_{1}D^{2}$
(D)	${}_{20}Ca^{40} + \text{........} \longrightarrow {}_{19}Ka^{37} + {}_{2}He^{4}$	s.	${}_{2}He^{4}$

MARK YOUR RESPONSE

1. | | p | q | r | s |
|---|---|---|---|---|
| A | ○ | ○ | ○ | ○ |
| B | ○ | ○ | ○ | ○ |
| C | ○ | ○ | ○ | ○ |
| D | ○ | ○ | ○ | ○ |

2. | | p | q | r | s |
|---|---|---|---|---|
| A | ○ | ○ | ○ | ○ |
| B | ○ | ○ | ○ | ○ |
| C | ○ | ○ | ○ | ○ |
| D | ○ | ○ | ○ | ○ |

3. | | p | q | r | s |
|---|---|---|---|---|
| A | ○ | ○ | ○ | ○ |
| B | ○ | ○ | ○ | ○ |
| C | ○ | ○ | ○ | ○ |
| D | ○ | ○ | ○ | ○ |

4. | | p | q | r | s |
|---|---|---|---|---|
| A | ○ | ○ | ○ | ○ |
| B | ○ | ○ | ○ | ○ |
| C | ○ | ○ | ○ | ○ |
| D | ○ | ○ | ○ | ○ |

5. **Column I** | **Column II**

(A) $_{13}Al^{27} + {}_0n^1 \longrightarrow {}_{13}Al^{28} \downarrow {}_{11}Na^{24} + {}_2He^4$

(B) $_{11}Na^{23} + {}_0n^1 \longrightarrow {}_{11}Na^{24} \downarrow Na^{24} + \gamma\text{-rays}$

(C) $_{13}Al^{27} + {}_1H^1 \longrightarrow {}_{14}Si^{28} \downarrow {}_{12}Mg^{24} + {}_2He^4$

(D) $_{13}Al^{27} + {}_2He^4 \longrightarrow {}_{15}P^{31} \downarrow {}_{11}Si^{30} + {}_1H^1$

p. Radioactive capture

q. α-particles are produced

r. Transmutation caused by protons

s. Transmutation caused by α-particles

6. **Column I** | **Column II**

(A) Projectiles successfully used for nuclear disintegration

(B) Natural agents used for nuclear disintegration

(C) Artificial agents used for nuclear disintegration

(D) Used in transmutation, known as **photo-disintegration**

p. α-particles

q. Protons, deutron, neutron

r. Cosmic rays

s. γ-rays

MARK YOUR RESPONSE

5.	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

6.	p	q	r	s
A	ⓟ	ⓠ	ⓡ	ⓢ
B	ⓟ	ⓠ	ⓡ	ⓢ
C	ⓟ	ⓠ	ⓡ	ⓢ
D	ⓟ	ⓠ	ⓡ	ⓢ

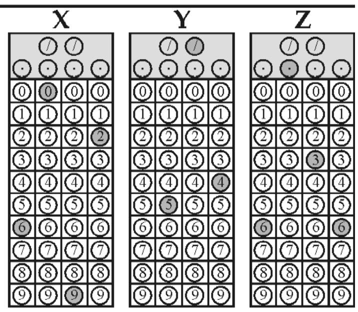
F NUMERIC/INTEGER ANSWER TYPE

The answer to each of the questions is either numeric (eg. 304, 40, 3010, 3 etc.) or a fraction (2/3, 23/7) or a decimal (2.35, 0.546).

The appropriate bubbles below the respective question numbers in the response grid have to be darkened.

For example, if the correct answers to question X, Y & Z are 6092, 5/4 & 6.36 respectively then the correct darkening of bubbles will look like the following.

For single digit integer answer darken the extreme right bubble only.



1. A mixture of Pu^{239} and Pu^{240} has specific activity of 6×10^9 dis sec^{-1}. The half-lives of isotopes are 2.44×10^4 and 6.58×10^3 years respectively. Calculate the percent of Pu^{239} in the mixture.

2. A solution of 1 litre has 0.56 g of non-radioactive Fe^{3+} with mass number 56. To this solution 0.228 g of radioactive Fe^{2+} is added with mass number 57 and the following reaction took place:

$$^{57}Fe^{2+} + ^{56}Fe^{3+} \longrightarrow ^{57}Fe^{3+} + ^{56}Fe^{2+}$$

At the end of one hour it was found that 10^{-5} moles of non-radioactive $^{56}Fe^{2+}$ was obtained and the rate of reaction was 3.40×10^{-7} mol lit^{-1} hr^{-1}. Neglecting any change in the volume, calculate activity of the sample (in terms of 10^{20} disintegrations/hr.) at the end of 1 hr. ($t_{1/2}$ for $^{56}Fe^{2+}$ = 4.62 hr)

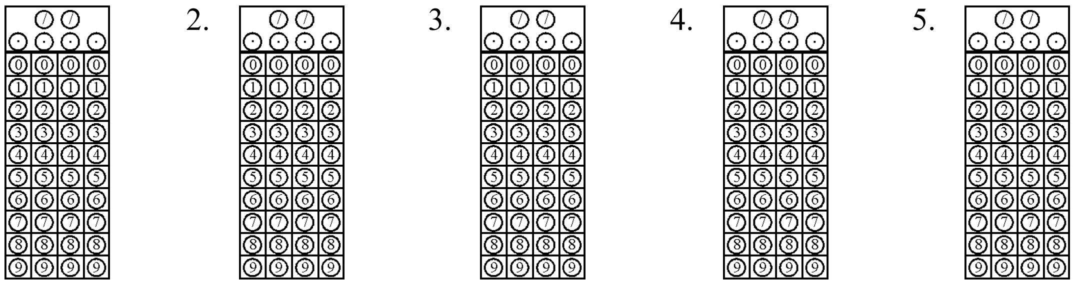
3. The naturally occuring isotope of rubidium (87) decays by beta emission to strontium (87). This decay forms the basis of a method for determination of the age of rocks. A sample of rock contains 120.1 μg of ^{87}Rb and 5.3 μg of ^{87}Sr. Find the age (in terms of 10^9 years) of the rock. Half-life of ^{87}Rb is 4.8×10^{10} years.

4. Upon irradiating californium with neutrons, a scientist discovered a new nuclide having mass number of 250 and half-life of 0.50 hr. Three hours after the irradiation, the observed activity due to nuclide was 10 dis min^{-1}. Calculate the number of nuclides initially formed. (in multiple of 10^4)

5. 1 g mixture of Co^{58} and Co^{59} has the activity of 2.2×10^{12} dis s^{-1}. Half-life of Co^{58} is 71.3 days. Find percent by mass of Co^{58} in the mixture.

MARK YOUR RESPONSE

1. 2. 3. 4. 5.



Answerkey

A SINGLE CORRECT CHOICE TYPE

1.	d	**2.**	b	**3.**	b	**4.**	c	**5.**	a	**6.**	d	**7.**	a	**8.**	d	**9.**	b	**10.**	a
11.	b	**12.**	d	**13.**	b	**14.**	c	**15.**	c	**16.**	c	**17.**	a	**18.**	c	**19.**	d	**20.**	d
21.	c	**22.**	b	**23.**	c	**24.**	d	**25.**	c	**26.**	b	**27.**	c	**28.**	b	**29.**	a	**30.**	b
31.	a	**32.**	a	**33.**	d	**34.**	b	**35.**	a	**36.**	c	**37.**	d	**38.**	d	**39.**	b	**40.**	d
41.	c	**42.**	c	**43.**	b	**44.**	d	**45.**	d	**46.**	a	**47.**	c	**48.**	a	**49.**	d	**50.**	b
51.	a	**52.**	d	**53.**	b	**54**	c	**55**	c	**56**	d	**57**	c	**58**	b	**59**	a	**60**	c
61	d	**62**	d	**63**	b	**64**	b	**65**	b	**66**	d								

B COMPREHENSION TYPE

1	(b)	**6**	(c)	**11**	(c)	**16**	(b)
2	(d)	**7**	(d)	**12**	(a)	**17**	(c)
3	(c)	**8**	(b)	**13**	(c)	**18**	(d)
4	(c)	**9**	(b)	**14**	(b)	**19**	(c)
5	(c)	**10**	(a)	**15**	(c)		

C REASONING TYPE

1	(a)	**3**	(b)	**5**	(a)	**7**	(c)	**9**	(a)	**11**	(a)	**13**	(c)	**15**	(b)
2	(d)	**4**	(c)	**6**	(c)	**8**	(c)	**10**	(c)	**12**	(b)	**14**	(b)	**16**	(b)

D MULTIPLE CORRECT CHOICE TYPE

1.	a,c,d	**2.**	b,c	**3.**	a,b,d	**4.**	b,c	**5.**	a,b,c	**6.**	a,b,d	**7.**	b,c
8.	c,d	**9.**	a,c,d	**10.**	b,d	**11.**	c,d	**12.**	b,c	**13.**	b, c, d	**14**	a,c,d
15	c	**16**	c,d	**17**	c,d	**18**	a,b,d						

E MATRIX-MATCH TYPE

1. **A-r; B-s; C-p; D-q**
2. **A-q, r; B-s; C-p; D-q, r**
3. **A-r; B-p; C-s; D-q;**
4. **A-r; B-s; C-p; D-q;**
5. **A-q; B-p; C-q, r; D-s**
6. **A-p, q, r, s; B-p, r, s; C-q; D- s**

F NUMERIC/INTEGER ANSWER TYPE

1	39	**2**	3.11	**3**	2.996	**4**	2.77	**5**	0.188

Solutions

A SINGLE CORRECT CHOICE TYPE

1. **(d)** O^{16} is doubly magic. $p = 8, n = 8$
2. **(b)** Co^{58} : Both p (= 27) and n (= 31) are odd.
3. **(b)** n/p ratio is too large, which decreases by β-emission.
5. **(a)** $\Delta m = (231.0363 + 4.0026) - 235.0439 = 0.0050$ u, $\Delta E = \Delta m \times 931.5$ MeV.
8. **(d)** Uranium series (starting nuclide U-238) is 4n + 2.
9. **(b)** $_{90}Th^{230} + {}_1H^1 \xrightarrow{-\alpha} {}_{89}Ac^{227} \xrightarrow{-\alpha} {}_{87}Fr^{223}$
10. **(a)** $_{92}U^{235} \rightarrow {}_{82}Pb^{207} + x\ {}_2He^4 + y\ {}_{-1}e^0$

Equating the mass numbers of both sides, 235 = 207 + $4x \Rightarrow x = 7$

Equating the atomic number of both sides, 92 = 82 + $2x - y = 82 + 2 \times 7 - y \Rightarrow y = 4$

12. **(d)** $\frac{n}{p}\left(=\frac{6}{7}\right)$ for N^{13} is too small.
14. **(c)** $t = \frac{1}{\lambda}\ln\frac{N_0}{N} = \frac{1}{\lambda}\ln\frac{1}{1/3} = \frac{1}{\lambda}\ln 3$ .....(i)

and $0.5t = \frac{1}{\lambda}\ln\frac{1}{x}$ (x fraction left) ......(ii)

From (i) and (ii) $x = \frac{1}{\sqrt{3}}$

15. **(c)** Equal fractions decay in equal periods of time.

Fraction remaining undecayed after one day

$= \frac{9}{100} = 0.9$

Fraction remaining undecayed after 2 days = 0.9^2 = 0.81

17. **(a)** $1 + \frac{Pb}{U} = 1 + 1 = 2 = \frac{U + Pb}{U} = \frac{N_0}{N}$

Hence, $t = \frac{2.303}{\lambda}\log\frac{N_0}{N}$; $\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{4.5 \times 10^9}$

Thus, $t = \frac{2.303 \times 4.5 \times 10^9}{0.693}\log 2 = 4.5 \times 10^9$ yr.

18. **(c)** Since $t_{1/2(A)} << t_{1/2(B)}$, the activity of B remains practically unchanged after 10 min.

Hence, $A + B = 10{,}000$ and $\frac{A}{2} + B = 7000$

or $A = 6000, B = 4000$

19. **(d)** $t_{20} = \frac{2.303}{\lambda}\log\frac{100}{100-20} = \frac{2.303}{\lambda}\log\frac{10}{8}$

$= \frac{2.303}{\lambda}[1 - 3\log 2]$

$t_{50} = \frac{2.303}{\lambda}\log\frac{100}{100-50} = \frac{2.303}{\lambda}\log 2$

$\frac{t_{50}}{t_{20}} = \frac{\log 2}{1 - 3\log 2} = 3$ or $t_{50} = 3\,t_{20} = 3t$

20. **(d)** $_{83}Bi^{211} \rightarrow {}_{81}Tl^{207} + {}_2He^4$

Fraction left $= \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^{\frac{4.30}{2.15}} = \frac{1}{4}$

Moles of He produced = moles of Bi decayed

$= 1 - \frac{1}{4} = 0.75$

Pressure developed due to He

$= \frac{22.4 \times 0.75}{10} = 1.68$ atm

22. **(b)** $t = \frac{2.303}{\lambda}\log\frac{100}{25} = \frac{2.303}{2.31 \times 10^{-3}}\log 2 = 300$ days
24. **(d)** (a), (b) and (c) belong to $4n + 3$ series but Ra^{221} belongs to $4n + 1$ series.
25. **(c)** $t = \frac{2.303}{\lambda}\log\frac{N_0}{N} = \frac{2.303 \times t_{1/2}}{0.693}\log\left[1 + \frac{Y}{X}\right]$

$= \frac{2.303 \times t_{1/2}}{2.303\log 2}\log\left[1 + \frac{7}{1}\right]$

$= \frac{t_{1/2}}{\log 2}\log 8 = \frac{t_{1/2} \times 3\log 2}{\log 2}$

$= 3\,t_{1/2} = 3 \times 1.37 \times 10^9$ yrs.

26. **(b)** At radioactive equilibrium, $\lambda_B N_{B(\max)} = \lambda_A N_A$

$$= \lambda_A N_0 e^{-\lambda_A t_{\max}} = \lambda_A N_0 e^{-\lambda_A \frac{2\ln 2}{\lambda_A}} = \lambda_A N_0 e^{\ln 2^{-2}}$$

$$= \frac{\lambda_A N_0}{4} \Rightarrow N_{B(\max)} = \frac{\lambda_A N_0}{4\lambda_B}$$

27. **(c)** $t = \frac{2.303}{\lambda}\log\frac{N_0}{N} = \frac{2.303\times t_{1/2}}{2.303\log 2}\log\left[1+\frac{\text{Pb}}{\text{U}}\right]$

$$= \frac{4.5\times10^9}{\log 2}\log\left[1+\frac{3}{1}\right] = \frac{4.5\times10^9\times 2\log 2}{\log 2}$$

$= 9\times10^9$ yrs.

29. **(a)** $t = \frac{2.303}{\lambda}\log\frac{N_0}{N} = \frac{2.303\times t_{1/2}}{0.693}\log\frac{1}{0.1}$

$$= \frac{2.303\times 6.931}{0.693} = 23 \text{ d}$$

30. **(b)** The momenta of fission fragments are equal.

$$K.E. = \frac{1}{2}mv^2 = \frac{m^2v^2}{2m} = \frac{p^2}{2m} \quad (p = \text{momentum})$$

$$\frac{\text{K.E. of lighter fragment}}{\text{K.E. of heavier fragment}} = \frac{E}{70} = \frac{144}{90}$$

$\Rightarrow E = 112$ MeV

Thus, total fission energy = 70 + 112 = 182 MeV

31. **(a)** Energy released = $180\times\frac{0.235}{235}\times 6.023\times10^{23}$ MeV

$= 1084.14\times10^{20}$ MeV $= 1084.14\times10^{26}\times1.602\times10^{-19}$ J

$= 1.73\times10^7$ kJ

34. **(b)** Activity $= 6.93 = \lambda N = \frac{0.693}{t_{1/2}}N \quad (t_{1/2} = 15 \text{ min.})$

$$= \frac{0.693\,N}{15} \Rightarrow N = 150$$

35. **(a)** Let $t_{1/2(A)} = 2$ min., then $t_{1/2(B)} = 3$ min.

Number of $t_{1/2(A)}$ elapsed = 3 ; number of $t_{1/2(B)}$ elapsed

$$= \frac{3\times 2}{3} = 2$$

Fraction of nuclide of A left $= \left(\frac{1}{2}\right)^3 = \frac{1}{8}$

Fraction of nuclide of B left $= \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

Hence, $\frac{n_A}{n_B} = \frac{1}{8} : \frac{1}{4} = 1:2$

36. **(c)** Number of nuclides remaining at time t, $N = N_0 e^{-\lambda t}$

Fraction decayed at time t

$$= \frac{N_0 - N}{N_0} = \frac{N_0 - N_0 e^{-\lambda t}}{N_0} = 1 - e^{-\lambda t}$$

37. **(d)** Let V ml of water be added. Then present activity of the diluted solution $= \frac{200x}{200+V}$ ml^{-1}

After 4 half-lives, the activity

$$= \frac{200x}{200+V}\times\left(\frac{1}{2}\right)^4 = \frac{x}{20} \text{ (given)} \Rightarrow V = 50 \text{ ml}$$

38. **(d)** Number of $t_{1/2(A)} = \frac{12}{2} = 6$;

number of $t_{1/2(B)} = \frac{12}{4} = 3$

$$n_A \text{ left} = \left(\frac{1}{2}\right)^6 = \frac{1}{64} \; ; n_B \text{ left} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$$

$$n_A : n_B = \frac{1}{64} : \frac{1}{8} = 1:8$$

39. **(b)** $X:\; N_0 \xrightarrow{30 \text{ min}} \frac{N_0}{2}$

$$Y:\; 4N_0 \xrightarrow{10 \text{ min}} 2N_0 \xrightarrow{20 \text{ min}} N_0 \xrightarrow{30 \text{ min}} \frac{N_0}{2}$$

40. **(d)** $t = \frac{2.303}{\lambda}\log\frac{A_0}{A_t} = \frac{2.303\times t_{1/2}}{2.303\log 2}\log\frac{100}{25}$

$$= \frac{t_{1/2}}{\log 2}\times\log 4 = \frac{5770\times 2\log 2}{\log 2} = 11540 \text{ yrs.}$$

41. **(c)** Fraction left

$$= \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^n = \frac{3.2\times10^8}{2\times10^7} = \frac{1}{16} = \left(\frac{1}{2}\right)^4$$

Time required $= 4\times t_{1/2} = 4\times 12.26$ yrs.

42. **(c)** Fraction left after first stage $= \frac{100-33.3}{100} = \frac{67.7}{100} = \frac{2}{3}$

Fraction left after second stage

$$= \frac{100-67.3}{100} = \frac{33.3}{100} = \frac{1}{3}$$

During the time interval of two stages, the element decays by 50%. Hence, time interval $= t_{1/2} = 30$ min.

43. **(b)** No. of half-lives of A in 2 days $= \frac{48}{12} = 4$

No. of half-lives of B in 2 days $= \frac{48}{16} = 3$

Amount of A left after 4 half-lives $= \left(\frac{1}{2}\right)^4 \times 4 = \frac{1}{4}$;

Amount of B left after 3 half-lives $= \left(\frac{1}{2}\right)^3 \times 1 = \frac{1}{8}$

Hence, $A : B = \frac{1}{4} : \frac{1}{8} = 2 : 1$

45. **(d)** Radioactive decay is a first order process. Hence the total number of radioactive nuclei will decrease exponentially with time.

46. **(a)** $N_x = N_0 e^{-\lambda t} = N_0 e^{-\lambda/9\lambda} = N_0 e^{-1/9}$

$N_y = N_0 e^{-10\lambda t} = N_0 e^{-10\lambda/9\lambda} = N_0 e^{-10/9}$

Hence, $\frac{N_x}{N_y} = \frac{e^{-1/9}}{e^{-10/9}} = e.$

47. **(c)** $(t_{1/2})_x = (t_{\text{mean}})_y$ or $\frac{0.693}{\lambda_x} = \frac{1}{\lambda_y}$

or $\lambda_x = 0.693\, \lambda_y$

Hence, $\lambda_x < \lambda_y$. Since rate of decay $= \lambda N$, Y will decay at a faster rate than X.

48. **(a)** $\lambda = \lambda_1 + \lambda_2 \qquad \frac{0.693}{t_{1/2}} = \frac{0.693}{t_{1/2(1)}} + \frac{0.693}{t_{1/2(2)}}$

$$t_{1/2} = \frac{t_{1/2(1)} \times t_{1/2(2)}}{t_{1/2(1)} + t_{1/2(2)}} = \frac{1620 \times 810}{1620 + 810} = 540 \text{ years}$$

Fraction left $= \frac{1}{4} = \left(\frac{1}{2}\right)^2$ No. of half-lives $= 2$

Hence, time required $= 2 \times 540 = 1080$ year

49. **(d)** Activity $A_1 = N_0 e^{-\lambda t_1}$, $A_2 = N_0 e^{-\lambda t_2}$

Hence, $\frac{A_2}{A_1} = \frac{e^{-\lambda t_2}}{e^{-\lambda t_1}} = e^{\lambda(t_1 - t_2)}$

50. **(b)** Mass of carbon in 7.32 g CO_2 $= \frac{12}{44} \times 7.32 = 2\text{g}$;

Activity per g (specific activity) $= \frac{7.6}{2} = 3.8$ dmp

Fraction of activity remaining $= \frac{3.8}{15.2} = \frac{1}{4} = \left(\frac{1}{2}\right)^2$

No. of half-lives elapsed = 2;
Age of the sample = 2 × 5730 years

51. **(a)** Activity of injected sample $= 1.0 \times 10^{-7} \times 3.7 \times 10^{10}$ $= 3.7 \times 10^3$ dps

Activity of 1 ml of blood $= \frac{22.2}{0.1 \times 60} = 3.7$dps

If V ml is the volume of the blood of animal, then $(V + 0.2) \times 3.7 = 3.7 \times 10^3 \Rightarrow V = 1000\text{ ml} = 1.0\text{ L}$

52. **(d)** 49.2 years is $\frac{49.1}{12.3} = 4$ half-lives

Fraction of $_1H^3$ remaining $\left(\frac{1}{2}\right)^4 = \frac{1}{16}$

$_1H^3$ atoms remaining $= \frac{1}{16} \times 8 \times 10^{-18} = 5 \times 10^{-19}$

No. of normal H-atoms = 1 (being non-radioactive does not change with time)

53. **(b)** $_{13}Al^{30}$ has an odd number of protons and odd number of neutrons. Hence, it is least likely to be stable.

54. **(c)** Nuclear isomers differ in energy states. The unstable isomer (more energetic) attains stability by conversion to less energetic species, known as **isomeric transition**.

55. **(c)** In isomeric transition there is no change in charge and mass of the nuclei.

56. **(d)** Nuclear isomerism is due to the difference in arrangement of nucleons and difference in energy of nucleons.

57. **(c)** Both these isomers (i.e. uranium X_2 and uranium Z_1 have same mass number (234) and same atomic number (91). Both are atoms of **protactinium**.

58. **(b)** A spallation reaction is not self sustaining like a fission reaction.

59. **(a)** In endoergic reaction (Q-value) is negative and the total mass of products is more than that of reactants.

60. **(c)** No proton is added to the nucleus. Nucleus contains only neutrons and protons and thus there is no electron present in the nucleus.

Due to decay of neutrons, electrons are produced which escape as β-emission and leave one proton in the nucleus due to which the atomic number increases.

61. **(d)** A neutron decays to produce an electron, a proton and a neutrino.

62. **(d)** All the given statements are correct.

63. **(b)** It is called (4n + 2) series.

It involves total 14 steps out of which 8 are α-emissions and 6 β-emissions.

64. **(b)** Radioactive equilibrium, unlike chemical equilibrium, is not reversible.

All other statements are correct.

65. **(b)** It is called **Boral**.

66. **(d)** All the statements (i.e., (a), (b), (c)) are correct and thus (d) is incorrect.

B COMPREHENSION TYPE

1. **(b)** The sum of atomic numbers and mass number for equation must be the same on both sides of equation.

$$^{14}_{7}N + ^{4}_{2}He \longrightarrow ^{x}_{y}Z + ^{17}_{8}O\ ;\ 14 + 4 = x + 17;\ x = 1$$

$$7 + 2 = y + 8\ ;\ y = 1$$

Therefore Z is H, a proton.

2. **(d)** The α-particle (a helium nucleus $^{4}_{2}He$) is largest and doubly charged; thus it is worst particle for artificial transmutation. Protons and electrons have the same magnitude of charge (±1) but a proton is much larger than an electron. Neutron has no charge, it becomes the best particle for the described reaction.

3. **(c)** This is the shape of the graph of all natural radioactive decay processes (first order processes).

4. **(c)** Since a positron is positively charged, it would be attracted to the plate of opposite charge, negative.

5. **(c)** Kinetic energy $= \frac{1}{2}$ mass × (velocity)^2

$$2.257 \times 10^{-5}\,J = \frac{1}{2} \times 9.1 \times 10^{-31}\, v^2$$

$$\Rightarrow\ v = 7 \times 10^{7}\ ms^{-1}$$

6. **(c)** For Na-24, n/p ratio $\left(= \frac{13}{11}\right)$ is too high. Hence a β-particle ($^{0}_{-1}e$) will be emitted.

7. **(d)** For C-11, n/p ratio $\left(= \frac{5}{6}\right)$ is too low. Emission of positron ($^{+1}_{0}e$) gives $\frac{n}{p}$ ratio be $\frac{6}{5}$.

9. **(b)** ^{235}U rods, placed together, form a piece larger than the critical size which could undergo fission leading to explosion.

10. **(a)** In atomic bomb all the three neutrons produced from a ^{235}U splitting cause the fission of nuclei of ^{235}U to go out of control.

12. **(a)** Total energy produced over a period of 6 years

$= 2 \times 10^{6}$ watt-years

Hence, the power in watts

$$= \frac{2 \times 10^{6}\ \text{watt - years}}{6\ \text{years}} = 3.3 \times 10^{5}\ \text{Watt}$$

14. **(b)** Mass defect (Δm) = (2 × 0.005486 + 2 × 1.007277 + 2 × 1.008665) – (4.00390)

= (4.03298 – 4.00390) amu = 0.02908 amu

Hence binding energy = 0.02908 × 931.5 MeV

= 27.09 MeV

15. **(c)** The last proton in $_{6}C^{12}$ may be expressed as

$$_{5}B^{11} + _{1}H^{1} \longrightarrow _{6}C^{12}$$

Then (Δm), mass defect = (11.009305 + 1.0078 – 12.0) amu

= 0.017105 amu

Thus binding energy of last proton

= 0.017105 × 931.5 MeV = 16.0 MeV

16. **(b)** In this case the last neutron in $_{6}C^{12}$ may be expressed as

$$_{6}C^{11} + _{0}n^{1} \longrightarrow _{6}C^{12}$$

Mass defect, Δm = (11.010433 + 1.0087 – 12) amu

= 0.019133 amu

Thus binding energy = 0.019133 × 931.5 MeV

= 18.75 MeV

17. **(c)** Atoms having the same isotopic number are called **isodiaphers** (N-Z) or (A-$2Z$) of an atom is called its **isotopic number** or **isotopic excess**.

A nuclide and its decay product after emission of α-particles are known as Isodiaphers.

18. **(d)** Molecules having the **same number of atoms** and **same number of electrons** are known as **isosters**.

Here number of atoms = 2 (For both HCl and F_2)

Number of electrons = 18 (For both HCl and F_2)

19. **(c)** Atoms having same number of neutrons but different masses are known as **Isotones**.

C REASONING TYPE

1. **(a)** All the three have same atomic number i.e. 1 and different mass number 1, 2 and 3 respectively.
2. **(d)** α-particles are fast moving helium nuclei (He^{2+}) with energy about 6 - 16 × 10^{-13} J.
3. **(b)** α-particles are much heavier than β-particles and hence have higher momentum.
4. **(c)** γ-radiation can be stopped only by thickness of about 15-20 cm of lead.
5. **(a)** Reason is the correct explanation of Assertion.
6. **(c)** A meson has mass between that of electron and proton and its charge is +1, –1 and 0.
7. **(c)** Radioactivity of an element is independent of its physical state, its chemical environment or temperature, suggesting that it is a property of nucleus, i.e. nuclear phenomenon.
8. **(c)** Loss of α or β-particle is to change N/P ratio so that it lies within the stability belt. Loss of α-particle increases N/P ratio while loss of β-particle decreases N/P ratio.
9. **(a)** Reason is the correct explanation of Assertion.
10. **(c)** Neutrons emitted during first fission bombard more uranium atoms and the reaction goes on. It is called chain reaction.
11. **(a)** $_{92}U^{235} + {}_0n^1 \longrightarrow {}_{92}U^{239} \xrightarrow{-\beta} {}_{93}Np^{239} \xrightarrow{-\beta} {}_{94}Pu^{239}$

In breeder reactors, the neutrons produced from fission of U-235 are partly used to carry on the fission of U-235 and partly used to produce some other fissionable material.

12. **(b)** Since all the isotopes of an element are chemically equivalent, the monitored path of the isotope will indicate the path of the reaction.
13. **(c)** Nuclides having both even number of protons and neutrons have maximum stability. So the reason is incorrect. But the assertion is correct as $_{20}Ca^{40}$ has even number of neutrons and protons as compared to $_{13}Al^{30}$, which has odd neutrons and protons.
14. **(b)** Both assertion and reason are correct but reason is not the correct explanation of assertion because reason is in no way involved in the assertion.
15. **(b)** Both assertion and reason are correct but reason is not the correct explanation of assertion.

In radiactive capture the neutron capture occurs and then the compound nucleus formed emits γ-ray photon.

16. **(b)** Both assertion and reason are correct but reason is not the correct explanation of assertion. The reason deals with the low yield produced and the dependence of yield on the energy of α-particles. It gives no idea about the elements which give rise to artificial radioactivity on being bombarded by α-particles.

D MULTIPLE CORRECT CHOICE TYPE

14. **(a,c,d)** Radioactive disintegration rate is affected by temperature.
15. **(c)** For treatment of leukema P-32 is used.
16. **(c,d)** Oxides of thorium and plutonium are used as fuels in nuclear reactor.
17. **(c,d)** Graphite and cadmium are used as moderators.
18. **(a,b,d)** Except B-12, all others are β-emitters.

E MATRIX-MATCH TYPE

1. **A-r; B-s; C-p; D-q**

   (A) O^{16} is doubly magic. Hence most stable.

   (B) Co^{58} has odd number of protons (27) and odd number of neutrons (31). Hence most unstable.

2. **A-q, r; B-s; C-p; D-q, r**

   (A) $\frac{n}{p}$ ratio for Na^{24} $\frac{13}{11}$ 1

   Hence, Na^{24} emits β-particle leading to decrease in $\frac{n}{p}$ ratio.

   (B) $\frac{n}{p}$ ratio for C^{11} = 5/6 < 1. Hence positron will be emitted leading to increase in $\frac{n}{p}$ ratio.

   (D) $\frac{n}{p}$ ratio for $H^3 = \frac{2}{1} > 1$. Hence β-particle will be emitted.

5. **A-q; B-p; C-q, r; D-s**

   The commonest process which results from **neutron capture** is **radioactive capture**. In this capture compound nucleus emits one or more γ-ray photons as in case of **(B)**.

   α–ray particles are doubly charged helium ion (He^{2+}) and represented as $_2\mathbf{He^4}$.

   Protons are represented as $_1H^1$ (hydrogen nucleus)

6. **A-p, q, r, s; B-p, r, s; C-q; D- s**

   All the given particles (i.e. cosmic rays, γ-rays, α-particles, protons, neutrons and deutrons) have been successfully used as projectiles for nuclear disintegration.

   Atomic nuclei can also be disintegrated by bombarding them with **high energy photons**. This process is usually known as **photo disintegration**.

F NUMERIC/INTEGER ANSWER TYPE

1. **Ans : 39%**

   Specific activity of Pu^{239}

   $$\lambda N \quad \frac{0.693}{t_{1/2}} \times \frac{1}{239} \times 6.02 \times 10^{23}$$

   Specific activity of $Pu^{240} = \frac{.693}{t_{1/2}} \times \frac{1}{240} \times 6.02 \times 10^{23}$

   Let fraction of $Pu^{239} = x$ Fraction of $Pu^{240} = 1 - x$

   Specific activity of the mixture = x × specific activity of Pu^{239} + $(1 - x)$ × specific activity of Pu^{240}

   $$6 \times 10^9 \quad x \times \frac{0.693 \times 6.02 \times 10^{23}}{2.44 \times 10^4 \times 365 \times 24 \times 60 \times 60} \times \frac{1}{239}$$

   $$+ \frac{0.693 \times (1-x) \times 6.02 \times 10^{23}}{6.58 \times 10^3 \times 365 \times 24 \times 60 \times 60} \times \frac{1}{240}$$

   $$= 2.268 \times 10^9 x + (1 - x) \times 8.377 \times 10^9$$

   $$6 = 2.268\, x + (1 - x) \times 8.377 \Rightarrow x = 0.39 = \mathbf{39\%}$$

2. **Ans : 3.11×10^{20} dis hr^{-1}**

   $$^{57}Fe^{2} \; + {^{56}Fe^{3}} \longrightarrow {^{57}Fe^{3}} \quad {^{56}Fe^{2}}$$

   Number of moles of $^{57}Fe^2$ taken initially

   $$= \frac{0.228}{57} = 4 \times 10^{-3}$$

   $$\lambda \quad \frac{2.303}{t} \log \frac{N_0}{N}$$

   $$\frac{0.693}{4.62} \quad \frac{2.303}{1} \log \frac{4 \times 10^{-3}}{N} \Rightarrow N = 3.44 \times 10^{-3} \text{ mole}$$

   Rate of decay

   $$= \lambda N \times 6.02 \times 10^{23} \quad \frac{0.693}{4.62} \times 3.44 \times 10^{-3} \times 6.02 \times 10^{23}$$

   $$= 3.11 \times 10^{20} \text{ dis hr}^{-1}$$

3. **Ans : 2.996×10^9 yrs**

   $$^{87}Rb \longrightarrow {^{87}Sr} \quad {_{-1}e^0}$$

   Number of moles of ^{87}Rb in the rock (N)

   $$\frac{120.1 \times 10^{-6}}{87} \quad 1.38 \times 10^{-6}$$

   Number of moles of ^{87}Sr in the rock

   $$\frac{5.3 \times 10^{-6}}{87} \quad 0.06 \times 10^{-6}$$

   Number of moles of ^{87}Rb initially present (N_0)

   $$= 1.38 \times 10^{-6} + 0.06 \times 10^{-6} = 1.44 \times 10^{-6}$$

Now, $\lambda = \frac{2.303}{t}\log\frac{No}{N}$

$$\frac{0.693}{4.8\times10^{10}} = \frac{2.303}{t}\log\frac{1.44\times10^{-6}}{1.38\times10^{-6}}$$

$$t = \frac{2.303\times4.8\times10^{10}}{0.693}\log\frac{1.44\times10^{-6}}{1.38\times10^{-6}}$$

$= 2.996 \times 10^9$ yrs

4. Ans : $N_0 = 2.77 \times 10^4$

Rate of radioactive decay $= \lambda N$ (N = number of nuclides)

$$10 = \frac{0.693}{t_{1/2}}\times N = \frac{0.693}{0.5\times60}\times N \Rightarrow N = 433$$

Also, $\lambda = \frac{2.303}{t}\log\frac{N_0}{N}$

$$\frac{0.693}{t_{1/2}} = \frac{0.693}{0.5} = \frac{2.303}{3}\log\frac{N_0}{433}$$

$N_0 = 2.77 \times 10^4$ nuclides (initially present)

5. Ans : 0.188%

Let x g be the mass of Co^{58} in 1 g of the mixture.

Moles of $Co^{58} = \frac{x}{58}$

Number of Co^{58} atoms (N) $= \frac{x}{58}\times6.02\times10^{23}$

Activity rate $\lambda N = \frac{0.693}{t_{1/2}}\times N$

$$2.2\times10^{12} = \frac{0.693}{71.3\times24\times60\times60}\times\frac{x}{58}\times6.02\times10^{23}$$

$$x = 1.88\times10^{-3}\,g$$

Percent of $Co^{58} = 1.88 \times 10^{-3} \times 100 = 0.188\%$

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