Multiple Choice Questions I

13.1. Suppose we consider a large number of containers each containing initially 10000 atoms of a radioactive material with a half life of 1 year. After 1 year
(a) all the containers will have 5000 atoms of the material
(b) all the containers will contain the same number of atoms of the material but that number will only be approximately 5000
(c) the containers will in general have different numbers of the atoms of the material but their average will be close to 5000
(d) none of the containers can have more than 5000 atoms
Answer:
(c) the containers will in general have different numbers of the atoms of the material but their average will be close to 5000

13.2. The gravitational force between a H-atom and another particle of mass m will be given by Newton's law: $F = G\ M.m/r^2$, where r is in km and
(a) M = mproton + m electron
(b) M = mproton + melectron - B/c^2 (B = 13.6 eV)
(c) M is not related to the mass of the hydrogen atom
(d) M = mproton + m electron $|V|/c^2$ - ($|V|$ = magnitude of the potential energy of electron in the H-atom)
Answer:
(b) M = mproton + melectron - B/c^2 (B = 13.6 eV)

13.3. When a nucleus in an atom undergoes a radioactive decay, the electronic energy levels of the atom
(a) do not change for any type of radioactivity
(b) change for α and β radioactivity but not for γ-radioactivity
(c) change for α-radioactivity but not for others
(d) change for β-radioactivity but not for others
Answer:
(b) change for α and β radioactivity but not for γ-radioactivity

13.4. Mx and My denote the atomic masses of the parent and the daughter nuclei respectively in a radioactive decay. The Q-value for a β– decay is Q1 and that for a β + decay is Q2. If me denotes the mass of an electron, then which of the following statements is correct?
(a) Q1 = (Mx – My) c^2 and Q2 = (Mx – My – 2me)c^2
(b) Q1 = (Mx – My) c^2 and Q2 = (Mx – My)c^2
(c) Q1 = (Mx – My – 2me) c^2 and Q2 = (Mx – My +2 me)c^2
(d) Q1 = (Mx – My + 2me) c^2 and Q2 = (Mx – My +2 me)c^2
Answer:
(a) Q1 = (Mx – My) c^2 and Q2 = (Mx – My – 2me)c^2

13.5 Tritium is an isotope of hydrogen whose nucleus Triton contains 2 neutrons and 1 proton. Free neutrons decay into $p + \bar{e} + \bar{v}$ **. If one of the neutrons in Triton decays, it would transform into He3 nucleus. This does not happen. This is because**
(a) Triton energy is less than that of a He^3 nucleus
(b) the electron created in the beta decay process cannot remain in the nucleus
(c) both the neutrons in triton have to decay simultaneously resulting in a nucleus with 3 protons, which is not a He^3 nucleus

(d) because free neutrons decay due to external perturbations which is absent in a triton nucleus
Answer:
(a) Triton energy is less than that of a He^3 nucleus

13.6. Heavy stable nuclei have more neutrons than protons. This is because of the fact that
(a) neutrons are heavier than protons
(b) electrostatic force between protons are repulsive
(c) neutrons decay into protons through beta decay
(d) nuclear forces between neutrons are weaker than that between protons
Answer:
(b) electrostatic force between protons are repulsive

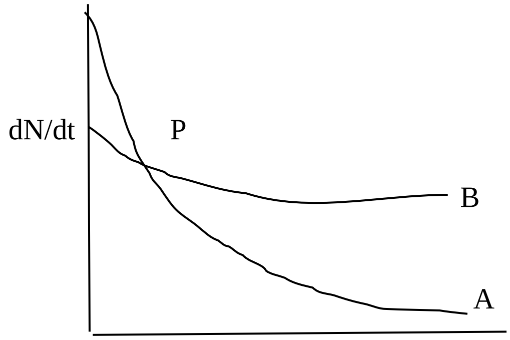
13.7. In a nuclear reactor, moderators slow down the neutrons which come out in a fission process. The moderator used have light nuclei. Heavy nuclei will not serve the purpose because
(a) they will break up
(b) elastic collision of neutrons with heavy nuclei will not slow them down
(c) the net weight of the reactor would be unbearably high
(d) substances with heavy nuclei do not occur in liquid or gaseous state at room temperature
Answer:
(b) elastic collision of neutrons with heavy nuclei will not slow them down

Multiple Choice Questions II

13.8. Fusion processes, like combining two deuterons to form a He nucleus are impossible at ordinary temperatures and pressure. The reasons for this can be traced to the fact:
(a) nuclear forces have short range
(b) nuclei are positively charged
(c) the original nuclei must be completely ionized before fusion can take place
(d) the original nuclei must first break up before combining with each other
Answer:
(a) nuclear forces have short range
(b) nuclei are positively charged

13.9. Samples of two radioactive nuclides A and B are taken. λA and λB are the disintegration constants of A and B respectively. In which of the following cases, the two samples can simultaneously have the same decay rate at any time?
(a) Initial rate of decay of A is twice the initial rate of decay of B and $\lambda A = \lambda B$
(b) Initial rate of decay of A is twice the initial rate of decay of B and $\lambda A > \lambda B$
(c) Initial rate of decay of B is twice the initial rate of decay of A and $\lambda A > \lambda B$
(d) Initial rate of decay of B is same as the rate of decay of A at t = 2h and $\lambda B < \lambda A$
Answer:
(b) Initial rate of decay of A is twice the initial rate of decay of B and $\lambda A > \lambda B$
(d) Initial rate of decay of B is same as the rate of decay of A at t = 2h and $\lambda B < \lambda A$

13.10. The variation of decay rate of two radioactive samples A and B with time is shown in the figure. Which of the following statements are true?

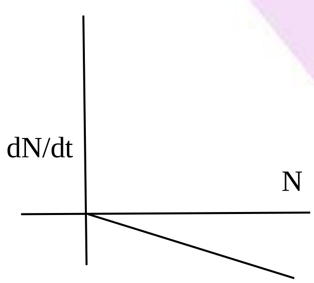


(a) Decay constant of A is greater than that of B, hence A always decays faster than B
(b) Decay constant of B is greater than that of A but its decay rate is always smaller than that of A
(c) Decay constant of A is greater than that of B but it does not always decay faster than B
(d) Decay constant of B is smaller than that of A but still its decay rate becomes equal to that of A at a later instant
Answer:
(c) Decay constant of A is greater than that of B but it does not always decay faster than B
(d) Decay constant of B is smaller than that of A but still its decay rate becomes equal to that of A at a later instant

Very Short Answers

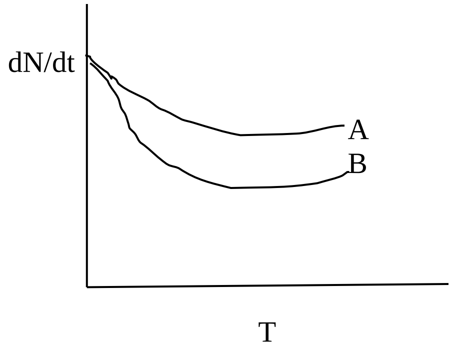
13.11. He_2^3 **and** He_1^3 **nuclei have the same mass number. Do they have the same binding energy?**
Answer:
$He2^3$ and $He1^3$ have the same mass number but the binding energy of these two nuclei is different. The binding energy of the $He1^3$ is greater than the $He2^3$ because the number of protons and neutrons present in both the nuclei are different. $He1^3$ has one proton and two neutrons while $He2^3$ has two protons and one neutron.

13.12. Draw a graph showing the variation of decay rate with number of active nuclei.



According to Rutherford and Soddy law, the radioactive decay is given as $-dN/dt = \lambda N$.

13.13. Which sample, A or B shown in the figure has shorter mean-life?



Answer:

At t= 0, (dN/dt)A = (dN/dt)B

dN/dt = -λN

$(N_o)A = (N_o)B$

λANA = λBNB

Na > NB

λB > λA

13.14. Which one of the following cannot emit radiation and why? Excited nucleus, excited electron.

Answer:

Excited electron cannot emit radiation because the energy of the electronic energy level is in the range of eV and not in MeV.

13.15. In pair annihilation, an electron and a positron destroy each other to produce gamma radiation. How is the momentum conserved?

Answer:

In pair annihilation, an electron and a positron destroy each other to produce gamma radiation and their momentum is conserved as they move in opposite directions to conserve the momentum.

Short Answers

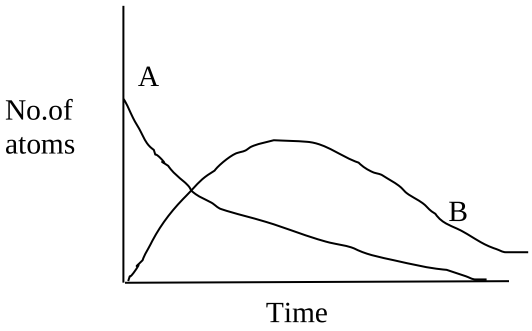
13.16. Why do stable nuclei never have more protons than neutrons?

Answer:

A stable nuclei never have more protons than neutrons because protons are charged particles and they repel each other. The repulsion is so much that excess neutrons only produce attractive forces and this is sufficient enough to build stability.

13.17. Consider a radioactive nucleus A which decays to a stable nucleus C through the following sequence: A → B → C Here B is an intermediate nuclei which is also radioactive. Considering that there are N_0 atoms of A initially, plot the graph showing the variation of number of atoms of A and B versus time.

Answer:



13.18. A piece of wood from the ruins of an ancient building was found to have a C^{14} activity of 12 disintegrations per minute per gram of its carbon content. The 14C activity of the living wood is 16 disintegrations per minute per gram. How long ago did the tree, from which the wooden sample came, die? Given half-life of C^{14} is 5760 years.

Answer:

C^{14} activity of a piece of wood from the ruins is R = 12 dis/min per gram

C^{14} activity of a living wood = Ro = 16 dis/min per gram

Half life of C^{14} = 5760 years

Using radioactive law,

$R = Roe^{-\lambda t}$

t = 2391.20 year

13.19. Are the nucleons fundamental particles, or do they consist of still smaller parts? One way to find out is to probe a nucleon just as Rutherford probed an atom. What should be the kinetic energy of an electron for it to be able to probe a nucleon? Assume the diameter of a nucleon to be approximately 10^{-15} m.

Answer:

$\lambda = h/p$ and kinetic energy = potential energy

$E = hc/\lambda$

Kinetic energy of an electron

$KE = PE = hc/\lambda = 10^9$ eV

13.20. A nuclide 1 is said to be the mirror isobar of nuclide 2 if Z1 =N2 and Z2 =N1.

(a) What nuclide is a mirror isobar of Na_{11}^{23} ?

(b) Which nuclide out of the two mirror isobars have greater binding energy and why?

Answer:

a) From question, we know that a nuclide 1 is to be the mirror isobar of nuclide 2

if

Z1 = N2 and Z2 = N1

Therefore, mirror isobar is Z2 = 12 – N1 and N2 = 23 -12 = 11 = Z1

b) Mg has greater binding energy than Na.

Long Answers

13.21. Sometimes a radioactive nucleus decays into a nucleus which itself is radioactive. An example is

$$Sulphur^{38} \xrightarrow[=2.48h]{half-life} Cl^{38} \xrightarrow[=0.62h]{half-life} Ar^{38}(stable)$$

Assume that we start with 1000 38S nuclei at time t = 0. The number of 38Cl is of count zero at t = 0 and will again be zero at t = ∞ . At what value of t, would the number of counts be a maximum?
Answer:
Let λ1 and λ2 be the disintegration constants for S38 and Cl38
dN1/dt = - λN1
dN2/dt = rate of decay of Cl38 + rate of formation of Gl38
dN2/dt = -λ2N2 + λ1N1
$e^{\lambda 2t}$dN2 + λ2N2$e^{\lambda 2t}$ dt = λ1No$e^{(\lambda 2 - \lambda 1)}$dt
Integrating the above equation we get,
t = 1.65 h

13.22. Deuteron is a bound state of a neutron and a proton with a binding energy B = 2.2 MeV. A γ -ray of energy E is aimed at a deuteron nucleus to try to break it into a (neutron + proton) such that the n and p move in the direction of the incident γ-ray. If E = B, show that this cannot happen. Hence calculate how much bigger than B must E be for such a process to happen.
Answer:
The binding energy of a deuteron = B = 2.2 MeV
Kn, Kp are the kinetic energies of neutron and proton
pn and pp are the momentum of neutron and proton
E – B = Kn + Kp
B must be $B^2/4mc^2$ for B to be much bigger than E.

13.23. The deuteron is bound by nuclear forces just as H-atom is made up of p and e bound by electrostatic forces. If we consider the force between neutron and proton in deuteron as given in the form of a Coulomb potential but with an effective charge e′: $F = \frac{1}{4\pi\epsilon_0}\frac{e'^2}{r}$ **estimate the value of (e'/e) given that the binding energy of a deuteron is 2.2 MeV.**
Answer:
The binding energy of H atom = E = 13.6 eV
The reduced m' = 918 m
The mass of a neutron or a proton is given as mp
The binding energy of the deutreron is 2.2 MeV
Therefore, the e'/e = 3.64

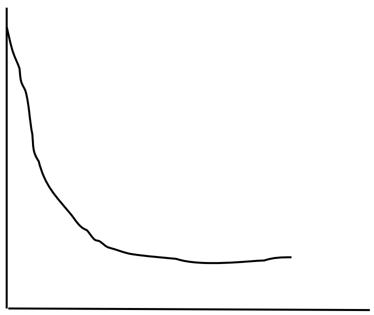
13.24. Before the neutrino hypothesis, the beta decay process was throught to be the transition, $n \rightarrow p + \bar{e}$ **If this was true, show that if the neutron was at rest, the proton and electron would emerge with fixed energies and calculate them. Experimentally, the electron energy was found to have a large range.**
Answer:
Let us consider cases before and after β-decay
Before β-decay, En = mnc^2 and pn = 0
After β-decay, pn = pp + pe
pc = mnc^2 – mpc^2 = 938 MeV – 936 MeV = 2 MeV

Ep = 936 MeV
Ee = 2.06 MeV

13.25. The activity R of an unknown radioactive nuclide is measured at hourly intervals. The results found are tabulated as follows:

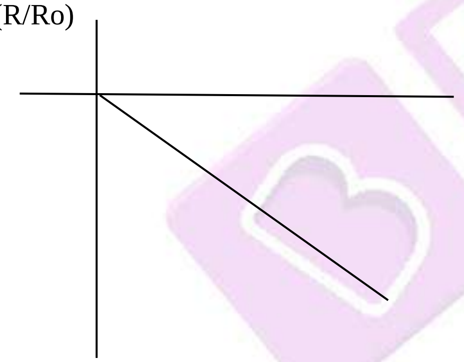
t(h)	**0**	**1**	**2**	**3**	**4**
R(MBq)	**100**	**35.36**	**12.51**	**4.42**	**1.56**

(i) Plot the graph of R versus t and calculate half-life from the graph.
(ii) Plot the graph of ln(R/R_0) versus t and obtain the value of half-life from the graph.
Answer:
i)



From graph we can say that the activity of R has reduced by 50%. Therefore, the half-life is 40 mins.

ii) ln(R/Ro)



Slope of the graph = - λ
$\lambda = 1.05\ h^{-1}$
Half-time = 0.693/ λ = 0.66 h = 39.6 min = 40 min

13.26. Nuclei with magic no. of proton Z = 2, 8, 20, 28, 50, 52 and magic no. of neutrons N = 2, 8, 20, 28, 50, 82 and 126 are found to be very stable
(i) Verify this by calculating the proton separation energy Sp for Sn120 (Z = 50) and Sb121 = (Z = 51). The proton separation energy for a nuclide is the minimum energy required to separate the least tightly bound proton from a nucleus of that nuclide. It is given by Sp = (M_{Z-1}, N + M_H – $M_{Z,N}$) c^2. Given In^{119} = 118.9058u, Sn^{120} = 119.902199u, Sb^{121} = 120.903824u, H^1 = 1.0078252u
(ii) What does the existence of magic number indicate?
Answer:
i) The proton separation energy is SpSn = (M119.70 + Mh – M120.70)c^2 = 0.0114362 c^2
Similarly SpSp = (M120.70 + Mh – M121.70)c^2 = 0.0059912 c^2
Sinec SpSn > SpSp, Sn nucleus is more stable than Sb nucleus.

ii) The magic numbers indicate that the shell structure of the nucleus is similar to the shell structure of the atom. This explains the peaks in the binding energy.