PHYSICS

BOOKS - ARIHANT PHYSICS (HINGLISH)

NUCLEAR PHYSICS

Others

1. Assume that an electron and a position pair is formed from a gamma ray photon having energy 3.0 MeV. Find the total kinetic energy of the positron and the electron that is formed.

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2. (a) Why is an alpha particle, rather than neutrons and protons, emitted from an unstable nucleus? (b) A nucleus $.^{A}X$ alpha decays to produce Y.

The vol- ume of nucleus Y is nearly 56 times the volume of alpha particle. Find the mass number (A) of X.

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3. A radionuclide has a half life of 10 s. Which of the following statements are correct? (a) In a sample, probability that a nucleus will decay in next 10 s is 0.5. (b) In a sample, the probability that a nucleus which has survived first 10 s, will decay in next 10 s is 0.5. (c) The probability that a nucleus which has survived first 10 s, will decay in next 10 s is 0.25. (d) If a sample of radionuclide has 4 nuclei, two nuclei will decay in next 10 s.

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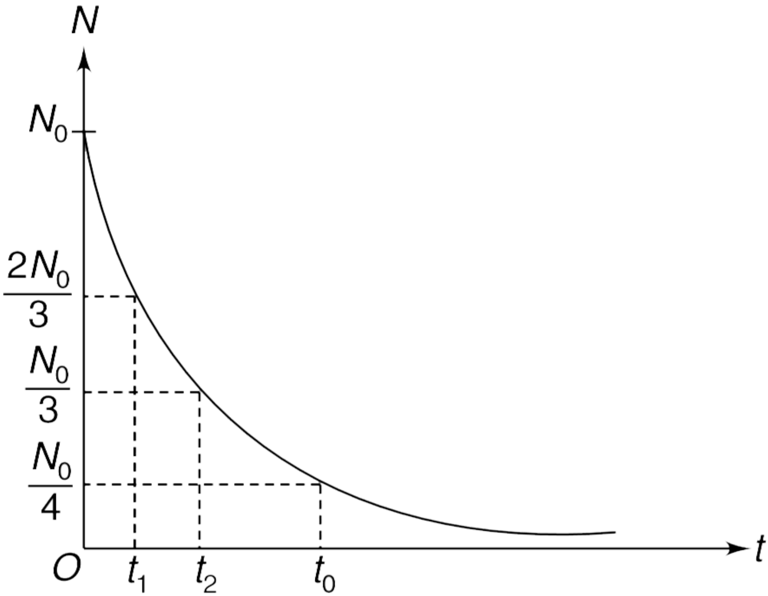
4. The population of active nuclei in a sample of radioactive isotope has been plotted with time in figure. Look at the graph carefully and find the value of $t_2 - t_1$. It is given that $t_0 = 50$ munite.



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5. (a) Assume that a particular nucleus, in a radioactive sample, has a probability ρ of decaying in the interval t to $t + \Delta t$. Taking that the nucleus actually does not decay in the above interval, what is probability that it will decay in the interval t $+ \Delta t$ to $t + 2\Delta t$?

(b) Find the mean life of $.^{55}C_0$ is its activity is known to decreases 4% per hour. $\ln\left(\frac{25}{24}\right) = 0.04$.

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6. A radioactive sample is a mixture of two radioactive species – one having population N_1has a mean life of T_1 and the other one having population N_2 has nuclei having mean life of t_2. Find the effective mean life of the nuclei in the mixture.

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7. An alpha active element has molar mass M and has a half life of τ. A large plate of thickness α is made from the radioactive element. Density of the plate is ρ. Calculate the number of alpha particles emitted in unit time from unit surface area of the plate. Avogadro's number is N_A.

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8. A radioactive isotope X decays into a stable nucleus Y. Draw graphs showing the variation of rate of formation of Y versus time and the

variation of population of Y versus time. Initial population of Y is zero.

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9. An excited $.^{69}\dot{Zn}$ Nucleus at rest decays to ground state $.^{69}Zn$ by way of emitting a gamma photon. The energy equivalent of difference in mass of $\dot{Zn}$ and Zn is 0.44 MeV. Calculate the kinetic energy of recol of Zn nucleus. Rest mass of $.^{69}Zn$ is $M_0 = 68.927u$.

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10. The α-decay of nucleus X^{230} is accompanied by emission of two groups of $\alpha-$ particles-one group having $\alpha-$ particles of kinetic energy 6.7MeV and other having α-particles of kinetic energy 5.2 MeV. Following the emission of these particles the daugheter muclei are found in ground and exiceted states. find the energy of gamma photon. that is subsequenctly emitted by de-exictation of the excited daughter nuclei. Assume that nuclei of X^{230} are at rest.

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11. In a nuclear reactor, the neutrons produced in fission reaction have high kinetic energy of the order of few MeV. Whereas the U^{235} nucleus fissions only iwht a slow neutron. In a reactor heavy water (D_2O) is used to slow down the neutrons. A neutron hiting a deuterium nucleus slows down quickly. Calculate now many head on, elastic collisions must a neutron have with deuterium nuclei to reduce does not lose energy by any other way apart from collisions with deuterium.

[Take $\log_{10}2 = 0.301$ and $\log_{10}3 = 0.477$]

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12. Consider the nuclear reaction

$._3^7 Li + ._1^1 H \rightarrow 2._2^4 He$

The relevant atomic masses are:

$.^7 : 7.018u, .^1 H : 1.008u, .^4 He : 4.004u.$

One gram of $.^1 H$ is compltely consumed in the reaction along with sufficient amount of $.^7 Li$. Find energy released.

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13. Beryllium necleus $\left(._{4}^{9}Be\right)$ when bombarded b alpha particle undergoes a nuclear reaction producing $._{6}^{12}C$. Binding energy per nucleon for different species are as under.

$BE_{Be}: 6.4763MeV, BE_{He}: 7.0819MeV,$

$BE_{C}: 7.6885MeV$

(a) Is there any other product (X) taht is formed apart from $\hat{}(17)C$?

(b) Calculate the energy relased in the reaction. Why don't we required Binding energy of X in this calculation?

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14. A sample contains two isotopes -one stale and the other unstable. Number of stable nuclei is equal to N_s and number of unstable nuclei is equal to N_u. After a time the activity of the sample decreased to one thrid of the, the initial activity while the total number of nuclei (excluding decayed nuclei) became half. find the initial value of the ratio N_s / N_u.

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15. In a beam of neurons the particles are having a kinetic energy of 0.0327eV. If the half life of neutron is 693 second. What fraction of neutrons will decay before the beam advances by 10m?

Given mass of neutron $= 1.675 \times 10^{27} kg.$

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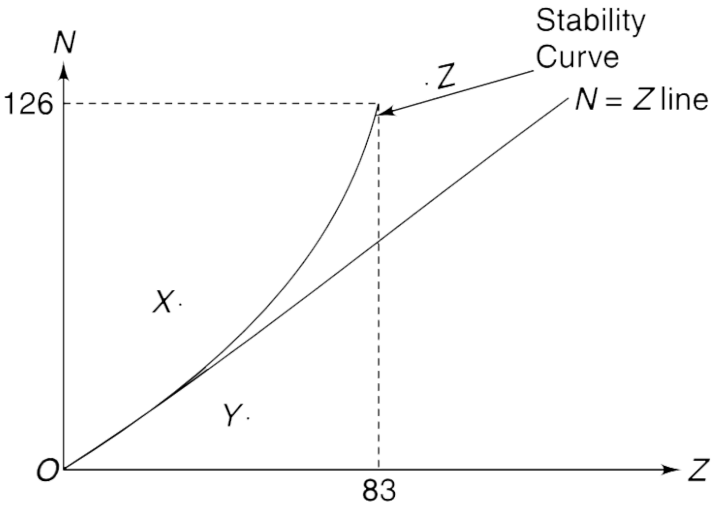
16. The figure shows a plot of number of neutron (N) versus number of protons (z) in all stable nuclei found in nature. What kind of decay are nuclei X,Y and Z expected to show?



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17. Which of the following isotopes is more stable and why?

(a) $._3^7 Li$ or $._3^8 Li$

(b) $._6^{13} C$ or $_(6)^{15} C$

(c) What kind of decay will be shown by the unstable nuclei in the above sets (a) and (b)?

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18. Consider the position emission reaction

$$._{z}^{A}X \rightarrow \underset{z-1}{A}Y +_{+} ._{1}^{0}e + v$$

Atomic mass of X and Y are m_x and m_y respectively and mass of a position is m_e

(a) Write the disintegration energy (Q) of the reaction.

(b) If $._{z}^{A}X$ is $._{6}^{11}C$ and atomic mass of ^{11}C is 11.011434 u, atomic mass of ^{11}B is 11.009305 u, mass of positron is $m_e = 0.000549u$, then find the maximum kinetic energy of emitted positron. $\left[(1u)c^2 = 930MeV\right]$

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19. Tritium $\left(._{1}^{3}H\right)$ is a radioactive isotope of hydrogen. It has a half life of about 12 years. It is produced in the upper atmosphere and is brought to the earth by rain. This mechanism replensihes the Tritium in water on the Earth. Estimicate the ageof a bottle of wine whose $._{1}^{3}H$ radiation is about $\left(\frac{1}{5}\right)^{th}$ of that of a new bottle. $[\log_{10}2 = 0.303]$.

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20. In the thorium decay series that begins with $.^{232}Th, .^{228}Th$ alpha-decays into $.^{224}Ra$ with a half life of 1.9yr. $.^{224}Ra$ alpha-decays into $.^{230}Rn$ with a half life of 3.7d, which in turn decays into $.^{216}Po$ with a half life of 55s. If the nuclides are in radioactive equilibrium in a mineral sample that contains 1.0g of $.^{220}Rn$, what are the masses of $.^{224}Ra$ abd $,^{228}Th$ in the sample?

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21. Nuclei of $.^{64}Cu$ can decay be electron capture (probability 61%) or by β^{+} decay (39%). Half life of $.^{64}Cu$ is 12.7 hour. Find the partial half life for electron capture decay oricess,

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22. In a sample there are two radioactive nuclide X and Y. Initially, population of X is 2.5 tiems that of Y. it was observed that 3 days later the population of X becomes 5.0 times that of population of Y. Find the half life of X it half life of Y is 2.0 days.

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23. It is known that the ratio of $.^{14}C$ to $.^{12}C$ atoms in living beings and atmosphere is a constant. In one experiment it was found that the radiocarbon activity of a living thing is 16 disintegration per minute per gram of carbon content. Find the ratio of $.^{14}C$ to $.^{12}C$ atoms in your body. Half life of beta decay of $.^{14}C$ is 5760yr=0.03×10^{9} minute.

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24. Taking the data from last problem and assuming that 18% of our body mass is made up of carbon, calculat e the number of beta particles being emitted from the body of a man of mass 50kg in one minute. Assume beta activity due to radiocarbon only.

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25. Consider the nuclear decay reaction.

$._z^A X \rightarrow \underset{z-1}{A} Y +_+ ._1^0 e + v$

For the above β^+ decay reaction to the feasible what should be the minimum difference in atomic masses of X and Y? Rest mass of v is nearly zero.

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26. The ratio (by weight) for U^{238} in a rock sample is 4:3. Assume that originally the rock had only U^{238} and the entire Pb^{226} is product of decay of U^{238}. The intermediate radioactive nuclides in the chain are very small in quantity in the rock.

Find the age of the rock if half life of U^{238} is 4.5×10^9 year.

$[\log_{10} 1.79 = 0.25, \log_{10} 2 = 0.3]$

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27. A radioactive species has decay constant of $\lambda = 10^{-2} s^{-1}$. Probability that a particular nucleus decays in time t is p. Draw a graph showing variation of ρ with t. Assume that the selected nucleus survives till last.

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28. A radioactive substance has a half life of t_0. Two particular nuclei-let's name them as nucleus A and B-have not decayed over a particular observation period of $6t_0$.

(a) What is the probability that A will decay over a further period of $3t_0$?

(b) What is the probability that both A and B will survive over a further period of $3t_0$?

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29. In a sample of radioactive material the probability that a particular nucleus will decay in next 2 hour is 8×10^{-4} find the half life of the

radioactive sample.

[Take $\ln 2 = 0.693, \ln(0.9992) = -8 \times 10^{-4}$]

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30. Atomic mass of $._3^7 Li$ is 7.01600u and that of $._4^7 Be$ is 7.01693u. Mass of one electron in atomic mass unit is 0.00055 u. if it is observed that $._4^7 Be$ decays into $._3^7 Li$, what kind of decay will it be?

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31. $._{15} P^{32}$ is beta active and has a short half life of 14 days. The $._{16} S^{12}$ nucleus produced is in ground state. On and average the emitted beta particles have 50% of the energy released in the reaction, remaining energy being carried by antineutrino. A liquid has small amount amount of P in it and it was found taht the liquid was receiving heat at a rate of about found that the liquid was receiving heat at a rate of about 10mW due to decay of P^{32}. It is to be noted that antineutrino do not intereact with matter easily and it would be safe to assume that they escape out of the contaienr. Estimate the number of P^{32} atom in the liquid. Relavent masses are

$P^{32} : 31.9740 u S^{32} : 31.9720 u e : 0.0005 u$

$1 \text{day} = 86400 s 1 u = \frac{931 MeV}{c^2}$

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32. A free neutron at rest, decays into three particles: a proton, an electron and an anti neutrino.

$._0^1 n \rightarrow ._1^1 P + ._{-1}^0 e + \overrightarrow{v}$

The rest masses are: $m_n = 939.5656 MeV / c^2$

$m_p = 938.2723 MeV / C^2 m_e = 0.5109 MeV / c^2$

In a particular decay, the antineutrino was found to have a total energy (including rest mass energy) of 0.0004 MeV and the momentum of proton was found to be equal to the momentum of electron. Find the kinetic energy of the electron.

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33. A radioactive nucleus A decay to C after emitting two α and three β particles. Another nucleus B decays to C by emitting one α and five β particles. Half life of A and B are 1 hr and 2hr respectively and all intermediates have negligible half lives. AT time t=0, population of C is zero.

(a) Find the difference in atomic numbers and mass numbers of A and B.

(b) Find the population of C when both A and B have equal population.

(c) Find time t_0 when both A and B have equal rate of decay.

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34. A nucleus at rest decays by emitting at α particle. The de-Broglie wavelenght of emitted α particle is $\lambda = -5.76$ femtometer. Mass of the daughter nucleus and α particle is 223.610u and 4.002u. Find the mass of the parent nucleus.

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35. A radioactive sample consists of two isotopes one of then decays by $\alpha -$ emission with a half life of $\tau_1 = 405s$ and the other one decays by β emission with half life of τ_1=1620s. $Attimet = 0, probabilitiesof \geq \in g$ alpha and beta

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alpha

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x^(4)+4x-2.5=0$then$x=0.59"log"_(10)2=0.301, "log"_(10)5.9=0.774`

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36. A deuterium nucleus at rest absorbs a Gamma ray photon of energy 2.21 MeV and splits into a proton and a neutron. The neutron was found to be at rest after the disintegration. Calculate the mass of proton if it is known that mass of deuterium and hydrogen atom is 2.014740u and 1.008145u respectively. $\left[1u = 931 MeV / c^2\right]$

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37. Two isotopes of radioactive Radon gas $-R_n^{222}$ and R_n^{220} are mixed in atomic ratio 1000:1 and kept in a $831 cm^3$ container at $10^5 N/m^2$ pressure and $27^\circ C$ temperature the two isotopes have half life of 4 days and 1 minute respectively. Calculate the activity of Radon gas sample in unit of curie.

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38. The Uranium -238 decay series (also known as 4n+2 series. Can you tell why?) ends at a stable isotope $.^{82} Pb^{206}$. Lead -206 is found in a certain Uranium ore due to dissintegration of Uranium.

(a) How many alpha and beta particles are emitted in the series decay of one $._{92} U^{238}$ nucleus into $._{82} Pb^{206}$?

(b) what is the age of uranium ore if it now contains 8g of Pb^{206} for every 10g of U^{238}? Hlaf life of U^{238} is 4.5 bilion year.

[Take $\ln 2 = 0.6930, \ln(1.9243) = 0.6546$]

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39. The half lives of two longest-lived radioactive isotopes of phosphorus P^{32} and P^{33}, are 14 days and 28 days respectively. A sample has been prepared by mxing the two isotopes in the ratio of 4:1 of their atoms. Initial activity of the mixed sample is 9.0mCi. Find the activity of the sample after 80 days.

Take $\ln 2 = 0.7$ and $e^{-2} = 0.14$

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40. A diatomic molecule moving at a speed u absorbs a photon of wavelenght λ and then dissociates into two identical atoms. One of the atoms is found to be moving with a speed v in a direction perpendicualr to the initial direction of motion of the molecule. Take mass of the molecule to be M and calculate the binding energy of the molecule. Assume that momentum of absorbed photon is negligible compared to that of the molecule.

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41. $A._{7}^{14}N$ nucleus, when bombarded by $._{2}^{4}He$, converts into $._{8}^{17}O$ accoring to the following reaction.

$._{7}^{14}N + ._{2}^{4}He \rightarrow ._{8}^{17}O + ._{1}^{1}H$

Atomic masses are:

$.^{14}N : 14.003u, .^{4}He : 4.003u, .^{17}O : 16.999u, .^{1}H : 1.008u$

(a) Find the Q value of the reactions

(b) Assume that a $.^{4}He$ nucleus collides with a free $.^{14}N$ nucleus originally at rest. Calculate the minimum kinetic energy (k_0) that $.^{4}He$ must have so as to cause this reaction.

(c) If the $.^{17}O$ nucleus has an excitation energy of 1.0 MeV, find the minimum kinetic energy (k_0) that $.^{4}He$ must have.

[Take $1u = 930MeV/c^2$]

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42. Following reactions are known as inverse beta decay

$p + \overrightarrow{v} \rightarrow n + e^{+}$

$n + v \rightarrow p + e^{-}$

These reactions have extremely low probabilities. Because of this, neutrinos and antineutrinos are able to pass through vast amount of matter without any interaction. In an experiment to detect neutrinos, large number of neutrinos coming out from beta decays of a radioactive material were made to pass through a tank of water, containing a cadmium compound in solution, which provided the protons to interact with antineutrinos, which provided the protons to interact with antineutrinos. Immediately after a proton absorbed a neutrino to yield a positron and a neutron, the positron encountered an electron and both got annihilated. the gamma ray detectors surrounding the tanks responded to the resulting photons. This confirmed that the above reaction has taken place.

(a) How many gamma ray photons are produced when a electron annihilates with a positron? What is energy of each photon? Take the mass of an electron to be 0.00055 u.

(b) The neutron produced in the above reaction was captured by $.^{112}Cd$ to form $.^{113}Cd$. The atomic masses of these two isotopes of cadmium are are 111.9028u and 112.9044u respectively. mass of a neutron is 1.0087u. find the Q value of this reaction. Assume half of this energy is excitation energ of $.^{113}Cd$. if the nucleus de-excites by emitting a gamma ray photon find its wavelenght.

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43. Consider the β^- decay of $._{12}^{27}Mg$

$._{12}^{27}Mg \rightarrow ._{13}^{27}Al^{\cdot} + ._{-1}^{0}e + \overrightarrow{v}$

The atomic masses of Mg^{27} and Al^{27} are 26.98434u and 26.98154u respectively. Mass of electron is 0.00055u. The Al^+ nucleus has excitively. Mass of electron is 1.015MeV.

(a) Find the Q value of the β^- decay.

(b) What is maximum possible kinetic energy of emitted β^- particle?

(c) Find the smallest wavelenght photon that Al^+ can emit when it de-excites.

(d) As an alternative to gamma decay, the excited Al^+ nucleus returns to its ground state by giving up its excitation energy to an atomic electron which has a binding energy of 2300eV. The process is known as internal conservation. Find the kinetic energy of the emitted electron.

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44. Moderator is used in a nuclear to slow down fast neutrons generated after a fission event in the reactor consider a fast neutron (mass m_n) moving at speed v. The neutron hits a moderator nucleus (Mass M), which is originally static, and gets scattered elastically by 180°

(a) Find te rato of kinetic energy of the neutron after and before collision.

(b) Show that when $M > > m_n$, neutron does not lose much energy and therefore, a moderator should have a small mass number.

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45. Two radioactive elements A and B are present in a mixture. Both are beta active. Half lives of A and B are 30 minute and 60 minute respectively. The initial activity of the sample hour only 30 beta particles were detected in an interval of 2 second. Assume that law of radioactivity decay is obeyed.

(a) Find the ratio of number of active of A to that of B in the mixture initially.

(b) The molar mass of both A and B is closed to 200g. The mixture contains other substance (non radioactive) aprt from A and B. what fraction of the entire mixure is radioactive (fraction by weight) if it is given what mass of the mixture is $1\mu g$.

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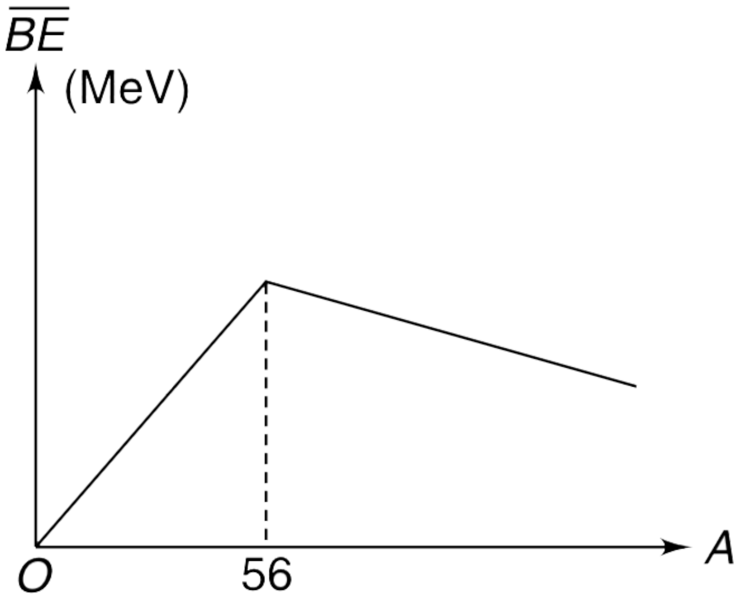
46. The graph of binding energy per nucleon $(\overline{B}E)$ versus mass number (A) for various nuclei has been approximated as made up of two linear components as shown in figure. The slope of line for $0 < A < 56$ is 0.16 and slope of line for $A56$ is -0.012. the binding energy of $._2^4He$ nucleus is 11 times the value predicted by the shown graph due to its very stable structure. Estimate the minimum mass number (A) of a nucleus for it to exhibit alpha decay.



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47. A rock sample has radioactive isotope A that decays into a stable product B. half life of A is 10^3 year. It was found that the rock sample contained n_1 moles of A and $\frac{n_1}{4}$ moles of b. Plot the variation of population of B with time. After how much time the rock will have equal population of A and B? [Given $2.^{0.68} = 1.6$]

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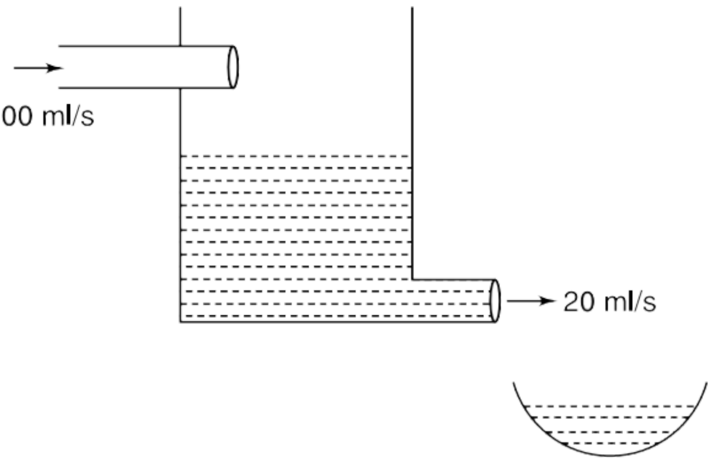
48. A 100 ml solution of a radioactive material has activity A_0. The solution is kept in a container and is diluted by adding water at a constant role of 100ml/sec. From a small hole in the container 20ml/sec of solution is taken out simultaneously. find the activity of the 100ml solution that is taken out in 5sec. Assume that the half life of radioactive material is very large and that the solution alwyas remains homogeneous.



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49. The ratio isotope $._{29}^{64}Cu$ can decay through positron emission and electron capture. In both the processes neutrino (v) is emitted. Calculate the difference in maximum possible kinetic energy of emitted neutrinos in the two processess.

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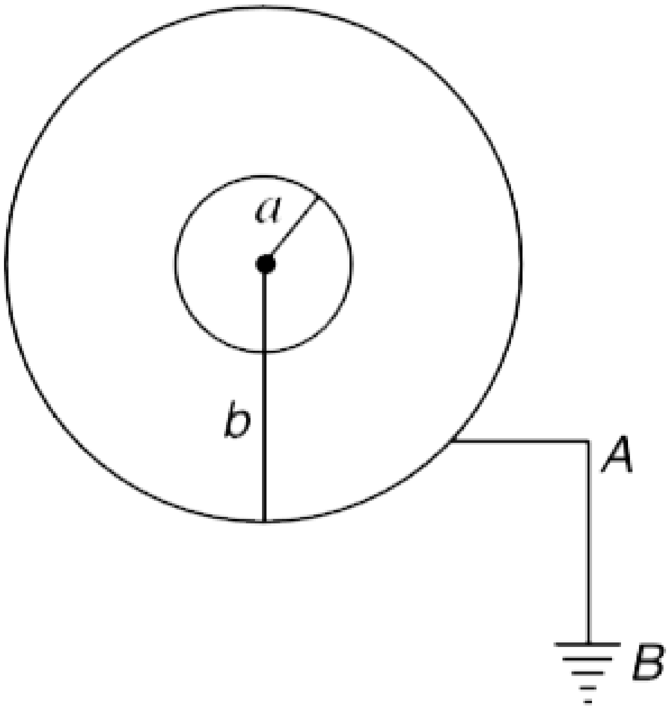
50. A β active radioactive source is in the form of a conducting sphere of radius a. it is surrounded by a concentric conducting shell of radius $b(> a)$. The shell is grounded. β particles are emitted with kinetic energy ranging from E_1 to $E_2(> E_1)$

(a) Find the maximum potential that will the acquired by the sphere of radius a.

(b) Find the total charge that will flow through the grounding wire AB.

(c) Find the final maximum charge on the outer sphre



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51. A radioactive isotope X decays simultaneously by two ways α and β decay. The decay constants of α and β decays are λ_1 and λ_2 and the products formed are Y and Z respectivley. Both Y and Z are stable. Initially. there was no presence of Y and Z in the sample. The process of α decay stops fater time t_0. Find the ratio of mass of Y to mass of Z in the sample at time $2t_0$ the molar masses of Y and Z are M_y and M_z respectively.

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52. The sun has a power of P=3.85 $\times 10^{26}$ W and the only source of energy in it is the following reaction

$4^1H \rightarrow .^4 He + 2e^+ + 2v_0$

The 'electron neutrinos (V_e)' are nearly mass less and carry negligible energy. However, they are able to escape from the sun and have been detected on the earth. The Earth-sun distance is $r = 1.5 \times 10^{11} m$ and masses of a hydrogen ato, helium atom and a positron are $1.6740 \times 10^{-27} kg$, $6.6450 \times 10^{-27} kg$ and $0.0009 \times 10^{-27} kg$ respectively.

(a) Calculate the flux density (i.e. number of neutrinos arriving at the Earth) in units of $m^{-2}s^{-1}$.

(b) While travelling from the Sun to the Earth, some of the electron neutrinos (V_e) are converted into other types of neutrinos $-v_0$. the dectector on the Earth has $\frac{1}{5}$ th efficiency for detecting v_0 as compared to its efficiency to detect v_0 Had there been no conversions of v_e. we expect to detect N_1 neutrinos in a year. However, due to conversion, we detect only N_2 neutrinos (v_0 and v_e combined) per year. what fraction (f) of v_e gets convertedinto v_0. express your answer in terms of N_1 and N_2.

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53. Consider a hypothetical case of a radinuclide A which produces a daughter B which is turn decays to a stable product C. the half life of B is 5 times that of A. take initial population of both B and C to be zero.

(a) Using qualitative arguments only, plot the variation of population of A,B and C with time.

(b) Find the ratio of population of B to that of A at the instant the population of B becomes maximum.

(c) Describe qualitatively how the slope of the graph of population oc C changes with time.

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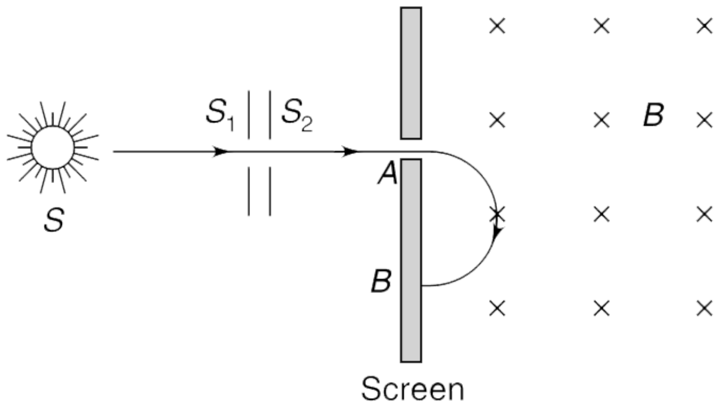
54. A source (s) of beta particles contains a radioactive isotope X. The emitted beta particles are passed through two parallel slits s_1 and s_2 to get a narrow parallel beam. This beam is made to enter a uniform magnetic field (B). The particles follow semicircular trajectories and are found to hit the screen at all points from A to B the distance AB is equal to 2a. The reaction for decay of a nucleus of X is

$X \rightarrow Y + ._{-1}^{0} e + \overrightarrow{v}$

Calculate the minimum difference in mass of a nucleus of X and Y. mass of an electron is m and charge on it its e.



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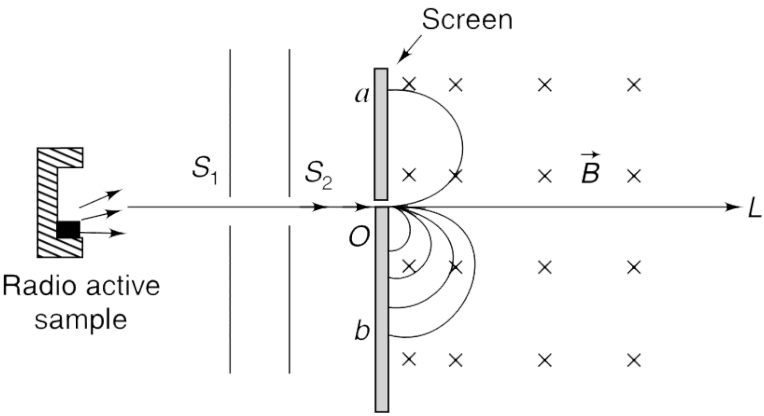
55. A sample of radioactive material has an alpha emitter (X) and a beta emitter (D). The energy of decay reactions are Q_1 and Q_2 respectively.

$$\cdot_Z^A X \rightarrow \cdot_{Z-2}^{A-4} Y + \cdot_2^4 He + Q_1$$

$$\cdot_{Z'}^{A'} D \rightarrow \cdot_{Z'+1}^{A'} B + \cdot_{-1}^{0} e + \vec{v} + Q_2$$

The radiation coming out from the sample is passed through two parallel slits S_1 and S_2 to get a narrow parallel beam to alpha and beta particles. This beam is allowed to enter perpendicularly into a region of inform magnetic field. The particles after taking a semicircular path strike the screen at a point a above the line L and, below the line L particles are found to strike the screen everwhere from O to b. the distance Oa and Ob and r_1 and r_2 respectively. Find the ratio $\frac{r_1}{r_2}$.

Take $\frac{Q_1}{Q_2} = k$ and assume that mass of alpha particles is 4 time the mass of a proton which is η times the mass of an electron.



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56. U^{238} decays in 14 steps that together consitute the net reaction

$${}_{92}U^{238} \rightarrow {}_{82}^{206}Pb + \dots + 6\vec{v} + 8({}_{2}^{4}He)$$

(a) Fill in the blank in the above reaction.

(b) The atomic masses of U^{238}, Pb^{206} and He^4 are 238.050783u. 205.97449u, and 4.002603u respectively. The energy equivalent of mass of one electron is 0.51 MeV. with this data calculate the Q value of the reaction.

(c) U^{238} has a long half life of $t = 4.47 \times 10^9$ yr. the other members in the chain reaction have relatively small half lives. As soon as a nucleus of

U^{238} decays the remaining steps are completed almost instataneously. with this assumption, calculate the power output from a 100kg block of pure U^{238}. the density of U^{238} is 18700 Kg/m^3.

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57. Some ratioisotopes are used for medical imaging . A radioisotope is injected into th blood of a person. Malignant tissue absorb and retian this isotope much more efficiently than other healthy tissues. A sample of radio isotope having half life of 5 hour and activity of 22mCi is injected into the blood aof a patient. the isotope enters into thyroid glnads through the blood streams. The isotope radiates gamma photons each having energy of $2 \times 10^{-8} \mu J$.

(a) Qualitatively sketch the amount of radio isotope in the thyroid glands as a function of time.

(b) Sometime after the injection a scan of the glands is taken over a period of 20 minute. The total energy emitted by the glands was found to be $6 \times 10^{-4} J$. Assume that the thyroid glands are quickly saturated (with isotopes) after the injection and almost 50% of the injected isotopes are absorbed by the glands. Make an estimate of the time after the injection when the scan was performed.

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58. A radioactive element is produced in nuclear reactor at a constant rate R(=numbers of nuclei per second). Its half-life is $T_{1/2}$. How much time, in terms of $T_{1/2}$. Is required to produce 50% of the equilibrium quantity of the radioactive element? is the result dependent of R?

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59. Nuclei of radioactive element A are produced at rate t^2 (where t is time) at any time t. The element A has decay constant λ. Let N be the number of nuclei of element A at any time t. At time $t = t_0$, dN/dt is minimum. The number of nuclei of element A at time $t = t_0$ is

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60. The power radiated by a star and its mass ma are related by $\frac{P}{P_0} = \left(\frac{m}{M_0}\right)^{7/2}$ where P_0 and M_0 are power radiated by the Sun and mass of the Sun respectively. Assume that the fraction of mass lost by the star since its birth is $\alpha(< \ < 1)$. Calculate the age of the star in terms of $\alpha, M_0 P$ and P_0.

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61. Rate of evaporation (volume evaporated per unit time) of water kept in an earthen pot is proportional to the volume of water present in the pot. It is observed that it takes 48 hrs for 75% of the water kept in the pot to evaporate. The empty pot was placed below a tap from which water leaks in small drops each of volume v_0. The drops fall at a uniform rate of n drops per hour. Calculate the volume of water in the pot 24hrs after it was kept below the tap.

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62. (a) The rest mass energy of an electron is $m_0c^2 = 0.51MeV$. Can a photon of this energy create an electron in free space?

(A) A single photon of energy $2m_0c^2$ or greater has enough energy to form an electron (e^-). Positron (e^+) pair. But prove that this process cannot occur in free space.

(c) The pair production is possibel in presence of a third particle. Assume that a photon having frequency v collides with a nucleus of rest mass M_0 (at rest) and creates an e^-, e^+ pair at rest. Calculate the mass M_0 of the nucleus.

Neglect relativistic effect in all questions.

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63. A radioactive nucleus A decays into B with a decay constnat λ_1. B is alos radioactive and it decays into C with a decay constant of λ_2. At time t=0 activity of A was recorded as A_1^0 and that of B was $A_2^0 = 0$, in a sample.

(a) If N_1 and N_2 are population of nuclei of A and B respectively at time t, set up a differential equation in N_2.

(b) The solution to the differential equation obtained in part(s) is given by

(b) The solution to the differential equation obtained in part (a) is given by

$$N_2 = \frac{\lambda_1}{\lambda_2 - \lambda_1} N_1^0 \left(e^{-\lambda_1 l} - e^{-\lambda_2 l}\right)$$

Where N_1^0 is initial population of A. Based on this answer following questions-

(i) If half life of A is quite large compared to B (for example hafl life of A is 8 hr and that of B is 1hr). show that ratio of activity of B to that of A approaches a constant value after a sufficiently long time. Find this ratio, in terms of λ_1 and λ_2.

(ii) If half of A is inifinitely large compared to that of B (for example, A has half life -10^9 yr and for B half life -10^5 yr), show that both A and B will have equal activity after a very long time.

(iii) If $\lambda_1 > \lambda_2$ find the time at which activity of B reaches a maximum.

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