Physics 111 Homework Solutions Collected on Thursday 11/13

Wednesday, November 12, 2014

Chapters 26

Questions

- none

Multiple-Choice

- none

Problems

- none

Thursday, November 13, 2014

Chapter 26

Questions

26.10 No it does not matter when each experimenter starts their respective experiments. Since the radioactive decay law can, for example, be written in terms of the activity of the radioactive sample, as long as the experimenters know their initial sample activity then the decay constant can be determined. The decay constant will be the same for both experimenters and thus the half-life can be calculated independent of the initial activity the experimenters started with.

Multiple-Choice

26.9 D
26.10 A
26.11 D

Problems

26.8 The total number of events per hour is given as the product of the number of phototubes and the number of events per hour per phototube. Thus the total number of events per hour is

$$\frac{\#\text{events}}{\text{hour}} = 110\text{phototubes} \times 0.027\frac{\text{events}}{\text{hour} \times \text{phototube}} = 2.97\frac{\text{events}}{\text{hour}}.$$

In order to figure out the fraction of the neutrinos that interact with the water in the tank we need to calculate the neutrino flux.

$$\text{neutrino flux} = \frac{\#\text{neutrinos}}{\text{second}} = 1\times10^{13}\frac{\text{neutrinos}}{\text{sec}\times\text{cm}^2} \times 4\text{m}^2 \times \frac{(100\text{cm})^2}{1\text{m}^2} = 4\times10^{17}\frac{\text{neutrinos}}{\text{sec}}.$$

Therefore the fraction of neutrinos that interacted is

$$\text{fraction} = \frac{2.97\text{events}}{3600\,\text{sec}} \times \frac{1\,\text{sec}}{4\times10^{17}} = 2.06\times10^{-21}.$$

26.13 The Chernobyl accident

a. The half-life is the time needed for ½ of the radioactive nuclei to disintegrate and we can relate the half-life to the decay constant. We have $\mathrm{N} = \frac{\mathrm{N}_0}{2} = \mathrm{N}_0 e^{-\lambda t_{\frac{1}{2}}} \rightarrow t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$ and the decay constant is therefore $\lambda = \frac{0.693}{t_{\frac{1}{2}}} = \frac{0.693}{8 days} = 0.0866 day^{-1}$

b. To calculate the storage time, we use the radioactive decay law with N = 0.15No. Therefore $0.15N_0 = N_0 e^{-\left(0.0866\mathrm{days}^{-1}\right)t} \rightarrow t = \frac{\ln(0.15)}{-0.0866\mathrm{days}^{-1}} = 21.9\mathrm{days}$.

26.15 We first determine the decay constant for palladium and we have $\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{17 days} = 0.041 days^{-1}$. Next we calculate the number of nuclei that remain after the 30 days from the radioactive decay law and find $N = N_o e^{-\lambda t} = N_o e^{-0.041 days^{-1} \times 30 days} = 0.292 N_o$ Therefore the number that have decayed is $N_{decayed} = 1 - 0.292 N_o = 0.708 N_o$. Further we know how much energy we need to destroy the tumor and we know the energy of the emitted gamma rays. Thus we can determine how many initial atoms we need. This produces $2.12J = 0.708 N_o \times 21000 eV \times \frac{1.6 \times 10^{-19} J}{1 eV} \rightarrow N_o = 8.92 \times 10^{14}$. Now that we know the initial number of radioactive atoms we can calculate the initial activity of the palladium and we find $A_o = \lambda N_0 = 0.041 days^{-1} \times 8.92 \times 10^{14} = 3.66 \times 10^{13} day^{-1}$. Lastly the initial mass of palladium can be calculated from $m = N_o m_{pd} = 8.92 \times 10^{14} \times 103 u \times \frac{1.66 \times 10^{-27} kg}{1 u} = 1.53 \times 10^{-10} kg = 15.3 ng$.

26.17 Here the initial mass M_0 = 1 and the final mass is 0.01% of the initial mass. Thus $M_f = 1 \times 10^{-4} M_0$. Referring to problem #7, the decay constant $\lambda = 0.024\ yr^{-1}$. From the radioactive decay law: $M_f = M_o e^{-\lambda t} \rightarrow 1 \times 10^{-4} M_0 = M_o e^{-\left(0.024\mathrm{yr}^{-1}\right)t} \rightarrow t = 383.4\mathrm{yrs}$.

26.18 The activity is given as the product λN, where λ is the decay constant and N is the number of nuclei that decay. Given that are sample is radium-226, with a half-life of 1600 years, we can calculate the decay constant. $\lambda = \frac{0.693}{t_{\frac{1}{2}}} = \frac{0.693}{1600 yrs} \times \frac{1 yr}{3.2 \times 10^7 \sec} = 1.35 \times 10^{-11} \sec^{-1}$. To calculate the number of nuclei present we use the mass given, 1g. There are 226 g of radium per mole and in 1 mole there are 6.02×10^{23} nuclei. Thus in 1 g there are 2.66×10^{21} nuclei. The activity is therefore $\lambda N = (1.35 \times 10^{-11}\ \sec^{-1})(2.66 \times 10^{21}\ \text{nuclei}) = 3.6 \times 10^{10}$ decays/sec = 3.6×10^{10} Bq.

26.19 The activity when the bone chip is measured is 0.5 decays/sec. The initial activity when the animal died needs to be determined. In the bone there is found 5g of carbon. Since 1 mole of carbon contains $6.02\text{x}10^{23}$ atoms and 1 mole of carbon has a mass of 12 g, there are $2.51\text{x}10^{23}$ carbon nuclei. Further the ration of $^{14}C/^{12}C$ has remained relatively constant and has a value of $1.3\text{x}10^{-12}$. Thus the number of ^{14}C nuclei is given as $(1.3\text{x}10^{-12})(2.51\text{x}10^{23}$ nuclei$) = 3.26\text{x}10^{11}$ ^{14}C nuclei when the animal died. The initial activity is a product of the decay constant and the number of ^{14}C nuclei present when the animal died. The decay constant is found from the half-life of carbon (5730yrs).

$\lambda = \frac{0.693}{t_{\frac{1}{2}}} = \frac{0.693}{5730 yrs} \times \frac{1 yr}{3.2 \times 10^7 \sec} = 3.78 \times 10^{-12} \sec^{-1}$. The initial activity is $\lambda N = (3.78\text{x}10^{-12} \sec^{-1})(3.26\text{x}10^{11}$ ^{14}C nuclei$) = 1.23$ Bq. To calculate the age of the bone we use the radioactive decay law

$$A = A_o e^{-\lambda t} \rightarrow 0.5 Bq = 1.23 Bq e^{-(3.78 \times 10^{-12} \sec^{-1})t} \rightarrow \ln(\frac{0.5}{1.23}) = -(3.78 \times 10^{-12} \sec^{-1})t$$

$$\rightarrow -0.902 = -(3.78 \times 10^{-12} \sec^{-1})t \rightarrow t = 2.39 \times 10^{11} \sec = 7456 yrs.$$

Since the bone is only about 7500 years old and knowing that the dinosaurs disappeared over 65 million years ago, it is probably not the bone of a dinosaur. Further since the activity for this bone chip is smaller than the bone chip found in problem #16, the age of the bone chip must be greater that that found in problem #16, so the answer seems reasonable, but not for a dinosaur bone.