EASTERN UNIVERSITY, SRI LANKA

THIRD EXAMINATION IN SCIENCE - 2002/2003

FIRST SEMESTER

(JUNE/JULY 2003)

PH 303 Nuclear Physics

Time: 01 hour.

Answer ALL Questions

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1. What is meant by

(i) Radioactive decay

(ii) Radioactive decay constant

(iii) Half-life

(iv) Uranium dating

(a) The fundamental law of radioactive decay may be written as

$$\frac{dN}{dt} = -\lambda N$$

State this equation in words. Hence show that the decay constant λ for a given material is related to its half-life $T_{\frac{1}{2}}$ by the equation

$$\lambda = \frac{0.6931}{T_{\frac{1}{2}}}$$

The presence of $^{238}_{92}U$ in a rock allow to estimate the age of the rock. Suppose that the ratio of $^{206}_{82}Pb$ to $^{238}_{92}U$ of the sample is 0.6, calculate the age of the rock. The half-life of $^{238}_{92}U$ is 4.5×10^9 years. What is the assumption you made in this calculation?

(b) Consider the decay scheme

$$X \longrightarrow Y \longrightarrow Z(\text{Stable})$$

The decay constant of X and Y are λ_1 and $\lambda_2 (\lambda_2 > \lambda_1)$ respectively. If initially (at $t = 0$) the number of atoms at Y is zero, show that at $t = t_m$ it would be maximum where

$$t_m = (\lambda_2 - \lambda_1)^{-1} \ln(\frac{\lambda_2}{\lambda_1})$$

2. Explain the meaning of the term mass defect and state the relationship between the mass defect and the binding energy of a nucleus.

Sketch a graph of nuclear binding energy per nucleon versus mass number for the naturally occurring isotopes and show how it may be used to account for the possibility of energy release by nuclear fission and by nuclear fussion.

One form of the binding energy equation of the liquid -drop model for a nucleus of nucleon number A, proton number Z and neutron number N is given by

$$\mathrm{Binding\ energy} = \mathrm{aA} - \mathrm{bA}^{\frac{2}{3}} - \mathrm{c}\frac{\mathrm{Z}^2}{\mathrm{A}^{\frac{1}{3}}} - \mathrm{d}\frac{(\mathrm{N}-\mathrm{Z})^2}{\mathrm{A}} \pm \mathrm{e}$$

Where a,b,c,d and e are constants. Explain briefly the significance of each term in the formula. Show for constant A the formula reduces to parabolic form

$$\mathrm{M(A,Z)} = \alpha\mathrm{A} + \beta\mathrm{Z} + \gamma\mathrm{Z}^2 \mp \mathrm{e}$$

Where α, β, γ, and e are function of A .

Hence show that for odd-A isobars

(a) $\mathrm{M(A,Z)} - \mathrm{M(A,Z_0)} = \gamma(\mathrm{Z}-\mathrm{Z_0})^2$, where Z_0 is the minimum value of the parabolic curve for constant A

(b) The total energy released or Q value in β^- decay

$$Q = 2\gamma\left[Z_0 - Z - \frac{1}{2}\right].$$

The β^- decay scheme of ${}^{131}_{52}Te$ and ${}^{131}_{53}I$ have Q values as indicated below

$${}^{131}_{52}Te \longrightarrow {}^{131}_{53}I + \beta^- + 2.16\mathrm{MeV}$$

$${}^{131}_{53}I \longrightarrow {}^{131}_{54}Xe + \beta^- + 0.97\mathrm{MeV}$$

Assume that the mass formula is applicable for these nuclei, find the local value of Z_0, γ and β.