EASTERN UNIVERSITY, SRI LANKA

THIRD EXAMINATION IN SCIENCE - 2008/2009

FIRST SEMESTER (PROPER)

(FEBRUARY 2010)

PH 303 NUCLEAR PHYSICS

Time: 01 hour.

Answer ALL Questions

You may find the following data useful:

1 MeV = 1.6×10^{-13}J

1 amu = 931.5 MeV/c^2

Avogadro number = 6.023×10^{23}

1. Define the terms Radioactive decay, Half life and Mean life of a radioactive sample.

(a) The fundamental law of radioactive decay is written as:

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

Show that the decay constant λ for a given material is related to its half life $T_{\frac{1}{2}}$.

A radioactive source contains 1 μg of uranium (U^{235}). The source is estimated to emit a total of 2000 α particles per second in all directions. Calculate the half-life of uranium.

(b) Consider the decay scheme: $X \rightarrow Y \rightarrow Z\ (stable)$

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

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

Consider the decay scheme: $X \overset{\beta}{\rightarrow} Y \overset{\beta}{\rightarrow} Z\ (stable)$

A freshly purified sample of X^{210} weighs 2.00×10^{-10}gm at time t = 0. If the sample is not disturbed, calculate the time at which the greatest number of atoms of Y will present and find this number.

(Half-life of X = 5 days and Half-life of Y = 138 days).

2. The binding energy E_B of a nucleus by the semi-empirical mass formula is given by:

$$B(A,Z) = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_A \frac{(A-2Z)^2}{A} \pm \delta,$$

$$\text{where } \delta = \begin{cases} +C_p A^{-3/4} & \text{- even 'A'} \\ 0 & \text{- odd 'A'} \\ -C_p A^{-3/4} & \text{- even 'A'} \end{cases}$$

Describe briefly the 'origin' of the various terms in the Semi-Empirical Mass Formula.

(a) Show that the mass of an atom can be written as:

$$M_A(A,Z) = \alpha A + \beta Z + \gamma Z^2 \mp \delta, \text{ where } \alpha, \beta, \gamma \text{ and } \delta \text{ are function of } A$$

(b) Show that the mass of any odd A isobar nuclide can be given as:

$$M_A(A,Z) = M_A(A,Z_0) + \gamma(Z - Z_0)^2$$

where Z_0 is the atomic number of the most stable isobar.

Calculate the energy released for the alpha particle emitted in the process:

$$U_{92}^{235} \rightarrow \alpha + Th_{90}^{231}$$

where the binding energy of the alpha particle is 28.3 MeV and you may assume the following values (in MeV) for the five coefficients, volume 15.5; surface 16.8; Coulomb 0.72; asymmetry 23 and pairing 34, in the semi-empirical expression for the binding energy of heavy nuclei.