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EASTERN UNIVERSITY, SRI LANKA

THIRD EXAMINATION IN SCIENCE-2010/2011

FIRST SEMESTER

APRIL/MAY 2013

PH 303 NUCLEAR PHYSICS

Time: 1 hour

Answer ALL Questions

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1. What is meant by the term "nuclear binding energy".

Explain in which way an atomic nucleus behaves like a liquid drop model.

The semi-empirical mass formula (SEMF) for a nucleus with atomic mass number A and atomic number Z can be expressed by

$$M_A(A,Z) = Zm_p + (A-Z)m_n - a_v A + a_s A^{\frac{1}{3}} + a_c \frac{Z(Z-1)}{A^{\frac{1}{3}}} + a_{asy}\frac{(A-2Z)^2}{A} + \delta$$

Explain the physical interpretation of the terms corresponding to the parameters a_v, a_s, a_c, a_{asy}, and δ.

(i) Show that for a constant A the SEMF can be reduced to a quadratic function of Z given by

$$M_A(A,Z) = \alpha A + \beta Z + \gamma Z^2 \mp \delta$$

where α, β, γ and δ are functions of A.

(ii) Show that the masses $M_A(A,Z)$ for a particular set of isobars with an odd A value takes the following form

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

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

(iii) Hence show that the energy released between neighbouring isobars in β^- decay is

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

For a typical β^- decay, illustrate the variation of Q_{β^-} on a scheme of $M_A(A,Z)$ versus Z.

2. Define scattering process and elastic scattering in nuclear physics.

In a laboratory reference frame, an incident particle of mass m_a and kinetic energy E_a is collides with a target nucleus X which is at rest. A residual nucleus Y of mass m_Y and kinetic energy E_Y results from the collision together with the emission of a product particle of mass m_b and kinetic energy E_b at an angle of θ to the direction of the incident particle. Under non-relativistic condition, show that the Q-value of the reaction is given by

$$Q = \left(\frac{m_a}{m_Y} - 1\right) E_a + \left(\frac{m_b}{m_Y} + 1\right) E_b - \frac{\sqrt{4 m_a m_b E_a E_b}}{m_Y} cos\theta.$$

The α particles of kinetic energy 7.70 MeV collides with ${}^{14}_{7}N$ target nuclei to produce ${}^{17}_{8}O$ residual nuclei and protons. The protons are emitted at 90° to the beam of α particles are found to have kinetic energy 4.44 MeV. Determine the Q value of the reaction.

Given that the

Mass of α particle m_α = 4.002604 a.m.u

Mass of proton m_p = 1.007825 a.m.u

Mass of oxygen m_O = 15.990523 a.m.u and

1 a.m.u = 931.5 MeV/c^2