866.

Problem 55.15 (RHK)

Consider the fission of $^{238}\mathrm{U}$ *by fast neutrons. In one fission event no neutrons were emitted and the final stable end products, after the beta decay of the primary fission fragments, were* $^{140}\mathrm{Ce}$ *and* $^{99}\mathrm{Ru}$. *We have to answer the following*: (a) *How many beta-decay events were there in the two beta-decay chains, considered together*? (b) *We have to calculate* Q. *The relevant atomic masses are*

$^{238}\mathrm{U}$	238.050784 u	$^{140}\mathrm{Ce}$	139.905433 u
n	1.008665 u	$^{99}\mathrm{Ru}$	98.905939 u.

Solution:

We consider a fission of $^{238}\mathrm{U}$ by fast neutrons in which no neutrons were emitted. The final stable end products, after the beta-decay of the primary fission fragments, are $^{140}\mathrm{Ce}$ and $^{99}\mathrm{Ru}$.

(a)

We note that as the atomic number of uranium, U, is 92, the conservation of charge tells us that the total combined number of protons in the primary fission fragments of the ^{238}U nuclide will also be 92.

The atomic number of cerium, Ce, is 58 and that of ruthenium, Ru, is 44 the combined number of protons in the Ce and Ru nuclides will be 102. Therefore, a total of 10 beta-decays would have taken place for 10 neutrons to have changed into 10 protons by emission of 10 electrons by beta emissions.

(b)

We will calculate the Q value for the fission by considering the effective nuclear process

$$\text{n} + {}^{238}\text{U} \rightarrow {}^{140}\text{Ce} + {}^{99}\text{Ru} + 10e^{-} + 10\bar{\upsilon}.$$

As we use the atomic masses instead of the masses of the nuclides, the Q will be given by

$$Q = \left(m_{\text{n}} + m_{^{238}\text{U}} - m_{^{140}\text{Ce}} - m_{^{99}\text{Ru}}\right)c^2$$

$$= \left(1.008665 + 238.050784 - 139.905433 - 98.905939\right)\text{u}c^2$$

$$= 0.248077\ \text{u}c^2$$

$$= 0.248077 \times 931.5\ \text{MeV} = 231\ \text{MeV}.$$