868.

Problem 55.17 (RHK)

Assume that just after the fission of $^{236}\mathrm{U}^*$ *according to the reaction*

$$^{236}\mathrm{U}^* \rightarrow {}^{140}\mathrm{Xe} + {}^{94}\mathrm{Sr} + 2\mathrm{n}$$

the resulting $^{140}\mathrm{Xe}$ *and* $^{94}\mathrm{Sr}$ *nuclei are just touching at their surfaces*. (a) *Assuming the nuclei to be spherical, we have to calculate the Coulomb potential energy* (*in* MeV) *of repulsion between the two fragments*. (b) *We have to compare this energy with the energy released in a typical fission process. We have to answer in what form this energy will ultimately appear in the laboratory*.

Solution:

(a)

The fission of $^{236}\mathrm{U}^*$ is assumed to place according to the reaction

$$^{236}\mathrm{U}^* \rightarrow {}^{140}\mathrm{Xe} + {}^{94}\mathrm{Sr} + 2\mathrm{n}.$$

We consider the situation when the resulting $^{140}\mathrm{Xe}$ and $^{94}\mathrm{Sr}$ nuclei are just touching at their surfaces. We will calculate the radii of ${}^{140}\mathrm{Xe}$ and ${}^{94}\mathrm{Sr}$ nuclides using the empirical relation

$$r = r_0 A^{1/3},$$

$$r_0 = 1.2\times 10^{-15}\ \mathrm{m}.$$

The radius of the ${}^{140}\mathrm{Xe}$ nuclide will therefore be

$$r_{{}^{140}\mathrm{Xe}} = 1.2\times(140)^{1/3}\times 10^{-15}\ \mathrm{m}$$
$$= 6.23\times 10^{-15}\ \mathrm{m}.$$

And, the radius of the ${}^{94}\mathrm{Sr}$ nuclide will be

$$r_{{}^{94}\mathrm{Sr}} = 1.2\times(94)^{1/3}\times 10^{-15}\ \mathrm{m}$$
$$= 5.46\times 10^{-15}\ \mathrm{m}.$$

The atomic number of ${}^{140}\mathrm{Xe}$ nuclide is 54 and the atomic number of ${}^{94}\mathrm{Sr}$ nuclide is 38. Therefore, the Coulomb potential energy between ${}^{140}\mathrm{Xe}$ and ${}^{94}\mathrm{Sr}$ nuclides, assuming that these nuclides are spherical and are just touching at their surfaces, will be

$$U = \frac{(54e)\times(38e)}{4\pi\varepsilon_0\left((6.23+5.46)\times 10^{-15}\right)}\ \mathrm{J}$$

$$= \frac{8.99\times 10^{9}\times 54\times 38\times\left(1.6\times 10^{-19}\right)^2}{11.69\times 10^{-15}}\ \mathrm{J}$$

$$= \frac{8.99\times 10^{9}\times 54\times 38\times\left(1.6\times 10^{-19}\right)^2}{11.69\times 10^{-15}\times 1.6\times 10^{-13}}\ \mathrm{MeV}$$

$$= 252\ \mathrm{MeV}.$$

(b)

The energy released in a typical fission process is about 200 MeV. This energy appears mainly in the laboratory as the kinetic energies of the fission neutrons.