Physics 112: General Physics II: Electricity, Magnetism, and Optics
Nuclear Fission

Problem 1: Complete the following fission reaction and determine the amount of energy it releases:

$$^{1}_{0}\mathrm{n} + {}^{235}_{92}\mathrm{U} \rightarrow {}^{88}_{38}\mathrm{Sr} + {}^{136}_{54}\mathrm{Xe} + (?)\ \text{neutrons}$$

First, tabulate some data from Appendix C (or a similar source):

Neutron	$^{1}_{0}\mathrm{n}$	1.008 665 u
Uranium-235	$^{235}_{92}\mathrm{U}$	235.043 930 u
Strontium-88	$^{88}_{38}\mathrm{Sr}$	87.905 612 u
Xenon-136	$^{136}_{54}\mathrm{Xe}$	135.907 219 u

a. How many neutrons are released?

b. How much energy is released by this reaction?

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a. How many neutrons are released?

On the left hand side of the reaction, the number of neutrons is

$$ N_{\text{initial}} = 1 + (235 - 92) = 144 $$

On the right hand side, the final number of neutrons listed is

$$ N_{\text{final}} = (88 - 38) + (136 - 54) = 132 $$

Therefore the number of extra neutrons is $144 - 132 = 12$. The reaction started with 1 incoming neturon, and generates 12 outgoing neutrons, each of which might initiate its own reaction. This leads to a “chain reaction” where the number of fission events increases rapidly.

b. How much energy is released by this reaction?

The initial and final masses are

$$ \begin{aligned} m_i &= m_n + m_{^{235}\mathrm{U}} = 1.008\,665\,\mathrm{u} + 235.043\,930\,\mathrm{u} = 236.052\,595\,\mathrm{u} \\ m_f &= m_{^{88}\mathrm{Sr}} + m_{^{136}\mathrm{Xe}} + 12 \times m_n \\ &= 87.905\,612\,\mathrm{u} + 135.907\,219\,\mathrm{u} + 12 \times 1.008\,665\,\mathrm{u} = 235.916\,810\,\mathrm{u} \end{aligned} $$

The mass difference Δm (and corresponding energy released Δmc^2) are

$$ \begin{aligned} \Delta m &= m_i - m_f = 236.052\,595\,\mathrm{u} - 235.916\,810\,\mathrm{u} = 0.135\,785\,\mathrm{u} \\ \Delta E &= (\Delta m)c^2 = (0.135\,785\,\mathrm{u}) \times \left(\frac{931.5\,\mathrm{MeV}}{(1\,\mathrm{u})c^2} \right) = 126\,\mathrm{MeV} \end{aligned} $$