823.

Problem 54.14 (RHK)

Because a nucleon is confined to a nucleus, we can take its uncertainty in position to be the approximately the nuclear radius R. Using the uncertainty principle, we have to estimate the kinetic energy of a nucleon in a nucleus with, say $A = 100$. *We may take the uncertainty in momentum* Δp *to be the actual momentum p.*

Solution:

For estimating the radius of a nucleus of mass number $A = 100$, we will use the empirical relation

$$R = R_0 A^{1/3}, \; R_0 = 1.2 \text{ fm} = 1.2 \times 10^{-15} \text{ m}.$$

Therefore, the radius *R* of a nucleus of mass number 100 will be

$$R = 1.2 \times 10^{-15} \times (100)^{1/3} \text{ m} = 5.57 \times 10^{-15} \text{ m}.$$

The Heisenberg uncertainty relation is

$$\Delta p \, \Delta x = \text{h}.$$

We take uncertainty in position to be approximately the nuclear radius *R*, i.e.

$$\Delta x = R = 5.57\times10^{-15}\ \text{m},$$

and uncertainty in momentum to be the momentum of the nucleon, i.e.

$$\Delta p = p.$$

Using the uncertainty relation, we find

$$p = \frac{\text{h}}{R} = \frac{1.05\times10^{-34}}{5.57\times10^{-15}}\ \text{kg m s}^{-1}$$

$$= 1.88\times10^{-20}\ \text{kg m s}^{-1}.$$

For the mass of a nucleon we take the mass of proton

$$m = 1.672\times10^{-27}\ \text{kg}.$$

Our estimate of the kinetic energy of a nucleon in a nucleus of mass number 100 is

$$KE_{\text{nucleon}} = \frac{p^2}{2m} = \frac{\left(1.88\times10^{-20}\right)^2}{2\times1.672\times10^{-27}}\ \text{J}$$

$$= 1.06\times10^{-13}\ \text{J} = \frac{1.06\times10^{-13}}{1.6\times10^{-13}}\ \text{MeV}$$

$$= 6.64\times10^{-1}\ \text{MeV}.$$