40. •• **Moderating a Neutron** In a nuclear reactor, neutrons released by nuclear fission must be slowed down before they can trigger additional reactions in other nuclei. To see what sort of material is most effective in slowing (or moderating) a neutron, calculate the ratio of a neutron's final kinetic energy to its initial kinetic energy, K_f/K_i, for a head-on elastic collision with each of the following stationary target particles. (*Note:* The mass of a neutron is $m = 1.009$ u, where the atomic mass unit, u, is defined as follows: $1\text{ u} = 1.66 \times 10^{-27}$ kg.) **(a)** An electron ($M = 5.49 \times 10^{-4}$ u). **(b)** A proton ($M = 1.007$ u). **(c)** The nucleus of a lead atom ($M = 207.2$ u).

Neutron ~~recoil~~ moderators

~~9.40~~ 9.40

$m_N \quad v_i \longrightarrow \bullet\ m_T$ $\qquad$ T = target

$$v_{1f} = \frac{m_1 - m_2}{m_1 + m_2} v_{1i}$$ (Eq 9.12) becomes

$$v_{Nf} = \left(\frac{m_N - m_T}{m_N + m_T}\right) v_{Ni}$$

$$\frac{K_f}{K_i} = \frac{\frac{1}{2} m_N v_{Nf}^2}{\frac{1}{2} m_N v_{Ni}^2} = \left(\frac{m_N - m_T}{m_N + m_T}\right)^2$$

(a) $m_N = 1.009\,u$

target = electron $m_e = 5.49 \times 10^{-4}\,u$

$$\frac{K_f}{K_i} = \left(\frac{1.009 - 5.49\times10^{-4}}{1.009 + 5.49\times10^{-4}}\right)^2 = \text{~~(0.9994)²~~} = \text{~~0.9989~~}\ 0.9978$$

Neutron continues on ~~undi~~ almost undisturbed.

(b) target = proton, $m_p = 1.007\,u$

$$\frac{K_f}{K_i} = \left(\frac{1.009 - 1.007}{1.009 + 1.007}\right)^2 = 9.8 \times 10^{-7}$$

almost stops

Best – water is a great moderator, in principle.

(c) target = lead, $m_{Pb} = 207.2\,u$

$$\frac{K_f}{K_i} = \left(\frac{1.009 - 207.2}{1.009 + 207.2}\right)^2 = 0.9807$$

just bounces back.

lead not too helpful!