

42. Conservation of linear momentum of the atom-photon system requires that

$$p_{\text{recoil}} = p_{\text{photon}} \implies m_p v_{\text{recoil}} = \frac{hf}{c}$$

where we use Eq. 39-7 for the photon and use the classical momentum formula for the atom (since we expect its speed to be much less than  $c$ ). Thus, from Eq. 40-6 and Table 38-3,

$$\begin{aligned} v_{\text{recoil}} &= \frac{\Delta E}{m_p c} = \frac{E_4 - E_1}{(m_p c^2)/c} \\ &= \frac{(-13.6 \text{ eV})(4^{-2} - 1^{-2})}{(938 \times 10^6 \text{ eV})/(2.998 \times 10^8 \text{ m/s})} \\ &= 4.1 \text{ m/s} . \end{aligned}$$