3. The conservation laws of (classical kinetic) energy and (linear) momentum determine the outcome of the collision. The results are given in Chapter 10, Eqs. 10-30 and 10-31. The final speed of the α particle is

$$v_{\alpha f} = \frac{m_\alpha - m_{\rm Au}}{m_\alpha + m_{\rm Au}}\, v_{\alpha i}\ ,$$

and that of the recoiling gold nucleus is

$$v_{{\rm Au},f} = \frac{2m_\alpha}{m_\alpha + m_{\rm Au}}\, v_{\alpha i}\ .$$

(a) Therefore, the kinetic energy of the recoiling nucleus is

$$\begin{aligned} K_{{\rm Au},f} &= \frac{1}{2} m_{\rm Au} v_{{\rm Au},f}^2 \\ &= \frac{1}{2} m_{\rm Au}\left(\frac{2m_\alpha}{m_\alpha + m_{\rm Au}}\right)^2 v_{\alpha i}^2 = K_{\alpha i}\frac{4m_{\rm Au}m_\alpha}{(m_\alpha + m_{\rm Au})^2} \\ &= (5.00\,{\rm MeV})\frac{4(197\,{\rm u})(4.00\,{\rm u})}{(4.00\,{\rm u} + 197\,{\rm u})^2} \\ &= 0.390\ {\rm MeV}\ . \end{aligned}$$

(b) The final kinetic energy of the alpha particle is

$$\begin{aligned} K_{\alpha f} &= \frac{1}{2} m_\alpha v_{\alpha f}^2 \\ &= \frac{1}{2} m_\alpha\left(\frac{m_\alpha - m_{\rm Au}}{m_\alpha + m_{\rm Au}}\right)^2 v_{\alpha i}^2 = K_{\alpha i}\left(\frac{m_\alpha - m_{\rm Au}}{m_\alpha + m_{\rm Au}}\right)^2 \\ &= (5.00\,{\rm MeV})\left(\frac{4.00\,{\rm u} - 197\,{\rm u}}{4.00\,{\rm u} + 197\,{\rm u}}\right)^2 \\ &= 4.61\ {\rm MeV}\ . \end{aligned}$$

We note that $K_{\alpha f} + K_{{\rm Au},f} = K_{\alpha i}$ is indeed satisfied.