48. (a) The nuclear reaction is written as ${}^{238}\mathrm{U} \rightarrow {}^{234}\mathrm{Th} + {}^{4}\mathrm{He}$. The energy released is

$$\begin{aligned}\Delta E_1 &= (m_{\mathrm{U}} - m_{\mathrm{He}} - m_{\mathrm{Th}})c^2 \\ &= (238.05079\,\mathrm{u} - 4.00260\,\mathrm{u} - 234.04363\,\mathrm{u})(931.5\,\mathrm{MeV/u}) \\ &= 4.25 \text{ MeV} .\end{aligned}$$

(b) The reaction series consists of ${}^{238}\mathrm{U} \rightarrow {}^{237}\mathrm{U} + n$, followed by

$$\begin{aligned}{}^{237}\mathrm{U} \rightarrow\ & {}^{236}\mathrm{Pa} + p \\ & {}^{236}\mathrm{Pa} \rightarrow {}^{235}\mathrm{Pa} + n \\ & \qquad {}^{235}\mathrm{Pa} \rightarrow {}^{234}\mathrm{Th} + p\end{aligned}$$

The net energy released is then

$$\begin{aligned}\Delta E_2 &= (m_{^{238}\mathrm{U}} - m_{^{237}\mathrm{U}} - m_n)c^2 + (m_{^{237}\mathrm{U}} - m_{^{236}\mathrm{Pa}} - m_p)c^2 \\ &\quad + (m_{^{236}\mathrm{Pa}} - m_{^{235}\mathrm{Pa}} - m_n)c^2 + (m_{^{235}\mathrm{Pa}} - m_{^{234}\mathrm{Th}} - m_p)c^2 \\ &= (m_{^{238}\mathrm{U}} - 2m_n - 2m_p - m_{^{234}\mathrm{Th}})c^2 \\ &= [238.05079\,\mathrm{u} - 2(1.00867\,\mathrm{u}) - 2(1.00783\,\mathrm{u}) - 234.04363\,\mathrm{u}](931.5\,\mathrm{MeV/u}) \\ &= -24.1 \text{ MeV} .\end{aligned}$$

(c) This leads us to conclude that the binding energy of the α particle is

$$\left|(2m_n + 2m_p - m_{\mathrm{He}})c^2\right| = |-24.1\,\mathrm{MeV} - 4.25\,\mathrm{MeV}| = 28.3 \text{ MeV} .$$