30.41

The decay reaction is ${}^{232}_{92}\mathrm{U} \longrightarrow {}^{228}_{90}\mathrm{Th} + {}^{4}_{2}\alpha$. Before the decay reaction the mass of the ${}^{232}_{92}\mathrm{U}$ *nuclide* is the mass of the ${}^{232}_{92}\mathrm{U}$ *atom* minus that of its 92 electrons: $m_{232} = 232.037\,13\,\mathrm{u} - 92m_e$, where m_e is the mass of an electron. After the decay the total rest mass of the products (an alpha particle plus a ${}^{228}_{90}\mathrm{Th}$ nuclide) is $m_\alpha + m_{228}$, where m_α is the mass of an alpha particle (i.e., a ${}^{4}_{2}\mathrm{He}$ nucleus), which equals the mass of a ${}^{4}_{2}\mathrm{He}$ *atom* minus that of its two electrons: $m_\alpha = m_{\mathrm{He}} - 2m_e = 4.002\,603\,\mathrm{u} - 2m_e$; and m_{228} is that of the ${}^{228}_{90}\mathrm{Th}$ nucleus, or that of the ${}^{228}_{90}\mathrm{Th}$ *atom* minus the mass of its 90 electrons: $m_{228} = 228.028\,73\,\mathrm{u} - 90m_e$. So as a result of the decay process the rest mass of the system changes by

$$\begin{aligned}\Delta m &= m_{232} - (m_\alpha + m_{228})\\ &= (232.037\,13\,\mathrm{u} - 92m_e) - [(4.002\,603\,\mathrm{u} - 2m_e) + (228.028\,73\,\mathrm{u} - 90m_e)]\\ &= 0.005\,797\,\mathrm{u}\,.\end{aligned}$$

Note that the electron masses cancel out. This mass difference corresponds to a disintegration energy of

$$Q = \Delta m\,c^2 = (0.005\,797\,\mathrm{u})(931.494\,\mathrm{MeV/u}) = 5.40\,\mathrm{MeV}\,,$$

which is the maximum amount of kinetic energy available to the decay products.

30.48

The number of electrons in a Po-210 atom is 84, which is equal to that in a lead (Pb)-206 (with 82 electrons) plus that in a He-4 atom (with 2 electrons). So the difference in the *nuclear* masses before and after the reaction (which is what we need) is the same as that in the *atomic* masses, as the mass of electrons cancels out. So we may use the atomic mass data given in the problem statement to find the change in mass in the decay process:

$$\begin{aligned}\Delta m &= m_{210} - (m_{206} + m_\alpha)\\ &= 209.982\,848\,\mathrm{u} - (205.974\,440\,\mathrm{u} + 4.002\,603\,\mathrm{u})\\ &= 0.005\,805\,\mathrm{u}\,.\end{aligned}$$

The corresponding disintegration energy is

$$Q = \Delta m\,c^2 = (0.005\,805\,\mathrm{u})(931.494\,\mathrm{MeV/u}) = 5.407\,\mathrm{MeV}\,,$$

which is the net kinetic energy of the decay products.

30.53

The decay constant λ is related to the half-life $t_{1/2}$ via Eq. (30.12), $\lambda t_{1/2} = 0.693$. Plug in $t_{1/2} = 1622\,\mathrm{y}$, along with the conversion factor $1\,\mathrm{y} = 3.155\,76 \times 10^7\,\mathrm{s}$, to obtain

$$\lambda = \frac{0.693}{t_{1/2}} = \frac{0.693}{(1622\,\mathrm{y})(3.155\,76 \times 10^7\,\mathrm{s/y})} = 1.35 \times 10^{-11}\,\mathrm{s}^{-1}\,.$$