Aufgabe 4

$1\,eV = 1.602 \cdot 10^{-19}\,J$

a.) $E_{kin} = 3 \cdot 10^{20}\,eV = 11.49\,cal \Rightarrow$ ausreichend 11.49 g Wasser um 1°C

b.) $E = E_0 + E_{kin} = \gamma m_0 c^2 = \gamma E_0$

$\Rightarrow \gamma = 1 + \frac{E_{kin}}{E_0} = 3.198 \cdot 10^{11}$ $\quad (E_0 = 938\,MeV = 938 \cdot 10^6\,eV)$

$\gamma = \frac{1}{\sqrt{1-\beta^2}} \Rightarrow \beta = \sqrt{1 - \frac{1}{\gamma^2}} = \left(1 + \left(-\frac{1}{\gamma^2}\right)\right)^{1/2} \approx 1 + \frac{1}{2}\left(-\frac{1}{\gamma^2}\right) = 1 - \frac{1}{2\gamma^2}$

$\Leftrightarrow 1 - \beta = \frac{1}{2\gamma^2} = 4.888 \cdot 10^{-24}$

c) $v \approx c \Rightarrow \Delta t_E = 25000\,a$

$\Delta t_p = \frac{1}{\gamma} \Delta t_E = 2.467\,s$

$1\,a = 60 \cdot 60 \cdot 24 \cdot 365{,}2425\,s$