Q1)

$$\begin{aligned} \beta_- &: {}^{196}Au \rightarrow {}^{196}Hg + e^- + \bar{\nu} \\ \beta_+ &: {}^{196}Au \rightarrow {}^{196}Pt + e^+ + \nu \\ \varepsilon &: {}^{196}Au + e^- \rightarrow {}^{196}Hg + \nu \end{aligned}$$

$$\begin{aligned} Q_{\beta_-} &= \left[m\left({}^{A}X\right) - m\left({}^{A}X'\right)\right]c^2 = [195.966544 - 195.965807] * 931.502\ MeV \\ &= 686.517\ keV \\ Q_{\beta_+} &= \left[m\left({}^{A}X\right) - m\left({}^{A}X'\right) - 2m_e\right]c^2 = \left[195.966544 - 195.964926 - 2 * 5.485803 \times 10^{-4}\right] * 931.502\ MeV \\ &= 485.163\ keV \\ Q_{\varepsilon} &= \left[m\left({}^{A}X\right) - m\left({}^{A}X'\right)\right]c^2 - B_n = [195.966544 - 195.964926] * 931.502\ MeV - 7.914861\ MeV \\ &= -6.40769\ keV \end{aligned}$$

Q2)

$$\begin{aligned} &a)\Delta I = 2; &&\Delta\pi = yes: \text{ First Forbidden} \\ &b)\Delta I = 2; &&\Delta\pi = no: \text{ Second Forbidden} \\ &c)\Delta I = 3; &&\Delta\pi = no: \text{ Second Forbidden} \\ &d)\Delta I = 0; &&\Delta\pi = no: \text{ Allowed Decay} \\ &e)\Delta I = 0; &&\Delta\pi = yes: \text{ First Forbidden} \end{aligned}$$

Q3)

First, we need to get the energy of the excited state of ${}^{20}Ne$ by employing conservation of Energy. E_1 represents the energy the excited state has over the ground state of ${}^{20}Ne$:

$$ {}^{20}Na \rightarrow {}^{20}Ne^* + e^+ + \nu $$

$$ E_1 = \left[m\left({}^{20}Na\right) - m\left({}^{20}Ne\right)\right] * c^2 - T_e $$

$$ E_1 = [20.007344 - 19.992436] * 931.502\ MeV - 5.55\ MeV = 8.34\ MeV $$

$$ {}^{20}Ne^* \rightarrow {}^{16}O + \alpha $$

$$ E_2 = \left[m\left({}^{20}Ne\right) - m\left({}^{16}O\right) - m\left({}^{4}He\right)\right] * c^2 $$

$$ E_2 = [19.992436 - 15.994915 - 4.002603] * 931.502\ MeV = -4.73389 $$

$$ Q = E_1 + E_2 = 8.34 - 4.73389 = 3.61\ MeV $$

$$ T_\alpha = \frac{Q}{1 + \frac{m_\alpha}{m_{X'}}} = \frac{3.61}{1 + \frac{4.00150618}{15.994915}}\ MeV = 2.89\ MeV $$

Q4)

a)

$$ \rho * R = 0.421 * E - 0.106 \implies R = \frac{0.421 * E^{-0.106}}{\rho} = \frac{0.412 * (3.58)^{-0.106}}{2.7} = 0.133\ cm $$

b) For Al $\mu/\rho = 5.006 \times 10^{-2} \implies \mu = 0.135\ cm^{-1}$. $t_{1/2} = 12.36\ hrs = 44496\ s$

$$ A_0 = 10\ mCi; \quad by\ \gamma: 2.5\ mCi $$

$$ A = A_0 e^{-\mu x} = 2.5e^{-0.135*0.133} = 2.46\ mCi = 91020000\ Decays/s $$

$$ N = \lambda A = \frac{\ln 2}{t_{1/2}} * A = \frac{\ln 2}{44496} * 91020000 = 1418\ photons $$

c)

$$ 1 - \frac{N}{N_0} = 1 - \frac{\frac{\ln 2}{t_{1/2}} * A}{\frac{\ln 2}{t_{1/2}} * A_0} = 1 - \frac{A}{A_0} = 1 - \frac{2.46}{2.5} = 0.016 = 1.6\%\ Absorbed $$

d) Compton Effect