13.2 Use tabulated rates (e.g., Caughlan and Fowler) to calculate the resonant and non-resonant contributions to the rate for $^{13}\text{N}(p,\gamma)^{14}\text{O}$ (with $Q = 4.628$ MeV) for temperatures relevant to main-sequence CNO reactions. Compare this rate, which will be strongly temperature dependent, with the constant rate expected for the competing beta decay assuming an appropriate density. The $(p,\gamma)$ velocity-averaged rate is

$$\langle \sigma v \rangle \simeq \frac{6.71 \times 10^{-17}}{T_9^{2/3}} e^{-15.2/T_9^{1/3}} + \frac{4.04 \times 10^{-19}}{T_9^{3/2}} e^{-6.35/T_9^{1/3}} \text{ cm}^3 \text{ s}^{-1},$$

where the first term is non-resonant and the second term is resonant. The beta decay constant is $\lambda = 1.159 \times 10^{-3}$ s$^{-1}$. To compare the two rates we convert the $(p,\gamma)$ rate to units of s$^{-1}$ by multiplying it by the proton density, $n_p = N_A X \rho$, where the first factor is Avogadro’s number, $X$ is the hydrogen mass fraction, and $\rho$ is the mass density. For example, the following figure compares these rates as a function of the temperature in units of $10^9$ K for the case $\rho = 100$ g cm$^{-3}$ and $X = 0.7$. In this figure the various curves show the total $(p,\gamma)$ rate, the separate contributions from the resonant and non-resonant terms (dashed lines), and the beta decay rate (dotted line), all in units of s$^{-1}$. 

![Graph comparing rates vs. temperature](image_url)