7.13

(a) $\frac{dN_2}{dt} = \frac{\sigma I_p}{h\nu}\left[\frac{g_2}{g_1} N_1 - N_2\right] - \frac{N_2}{\tau}$; There is no need to write a separate equation for N_1 since atoms must be conserved and thus $N_1 + N_2 = [N]$;

(b) If $I_p \to \infty$, then the bracket in the above must be zero to prevent an infinity appearing in a physical equation. Thus $N_2/N_1 = g_2/g_1$.

(c) For a steady-state situation: $N_2\left[1 + \frac{\sigma\tau}{h\nu} I_p\right] = \frac{g_2}{g_1}\frac{\sigma\tau}{h\nu} I_p N_1$ or $\frac{N_2}{N_1} = \frac{(g_2/g_1)\cdot(I_p/I_s)}{1 + (I_p/I_s)}$ where $I_s = \frac{h\nu}{\sigma\tau}$; This ratio equals 0.5 when $I_p/I_s = 0.25$ for $g_2/g_1 = 2$; $I_s = 23.3\ W/cm^2$; Thus $I = 5.82 W/cm^2$; (d) $N_2/N_1 = (g_2/g_1)\exp[-E/kT] = 6.25\times10^{-25}$; safe to ignore N_2.