36. (a) We use $eV = hc/\lambda_{\min}$ (see Eq. 40-23 and Eq. 38-4). With hc = 1240 eV·nm = 1240 keV·pm, the mean value of $\lambda_{\min}$ is

$$\lambda_{\min} = \frac{hc}{eV} = \frac{1240\,\text{keV}\cdot\text{pm}}{50.0\,\text{keV}} = 24.8\,\text{pm} .$$

(b) The values of λ for the K_α and K_β lines do not depend on the external potential and are therefore unchanged.

39. Since the frequency of an x-ray emission is proportional to $(Z - 1)^2$, where Z is the atomic number of the target atom, the ratio of the wavelength λ_{Nb} for the K_α line of niobium to the wavelength λ_{Ga} for the K_α line of gallium is given by

$$\lambda_{\text{Nb}}/\lambda_{\text{Ga}} = (Z_{\text{Ga}} - 1)^2 / (Z_{\text{Nb}} - 1)^2 ,$$

where Z_{Nb} is the atomic number of niobium (41) and Z_{Ga} is the atomic number of gallium (31). Thus,

$$\lambda_{\text{Nb}}/\lambda_{\text{Ga}} = (30)^2/(40)^2 = 9/16 \approx 0.563 .$$

52. The energy of the laser pulse is

$$E_p = P\Delta t = (2.80\times10^{6}\ \text{J/s})(0.500\times10^{-6}\ \text{s}) = 1.400\ \text{J} .$$

Since the energy carried by each photon is

$$E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\ \text{J}\cdot\text{s})(2.998\times10^{8}\,\text{m/s})}{424\times10^{-9}\ \text{m}} = 4.69\times10^{-19}\,\text{J} ,$$

the number of photons emitted in each pulse is

$$N = \frac{E_p}{E} = \frac{1.400\text{J}}{4.69\times10^{-19}\ \text{J}} = 3.0\times10^{18}\ \text{photons.}$$

With each atom undergoing stimulated emission only once, the number of atoms contributed to the pulse is also 3.0×10^{18}.

59. For stimulated emission to take place, we need a long-lived state above a short-lived state in both atoms. In addition, for the light emitted by A to cause stimulated emission of B, an energy match for the transitions is required. The above conditions are fulfilled for the transition from the 6.9 eV state (lifetime 3 ms) to 3.9 eV state (lifetime 3 μs) in A, and

the transition from 10.8 eV (lifetime 3 ms) to 7.8 eV (lifetime 3 μs) in B. Thus, the energy per photon of the stimulated emission of B is $10.8\text{ eV} - 7.8\text{ eV} = 3.0\text{ eV}$.

64. (a) In the lasing action the molecules are excited from energy level E_0 to energy level E_2. Thus the wavelength λ of the sunlight that causes this excitation satisfies

$$\Delta E = E_2 - E_0 = \frac{hc}{\lambda},$$

which gives (using hc = 1240 eV·nm)

$$\lambda = \frac{hc}{E_2 - E_0} = \frac{1240\text{ eV}\cdot\text{nm}}{0.289\text{ eV} - 0} = 4.29\times 10^3\text{ nm} = 4.29\ \mu\text{m}.$$

(b) Lasing occurs as electrons jump down from the higher energy level E_2 to the lower level E_1. Thus the lasing wavelength λ' satisfies

$$\Delta E' = E_2 - E_1 = \frac{hc}{\lambda'},$$

which gives

$$\lambda' = \frac{hc}{E_2 - E_1} = \frac{1240\text{ eV}\cdot\text{nm}}{0.289\text{ eV} - 0.165\text{ eV}} = 1.00\times 10^4\text{ nm} = 10.0\ \mu\text{m}.$$

(c) Both λ and λ' belong to the infrared region of the electromagnetic spectrum.