## Chapter 37 Problem 18 †

**Given**
$I = 1.75 \times 10^{-47}\ kg \cdot m^2$

**Solution**
Find the wavelength emitted going from $l = 5$ to $l = 4$.

The rotational energy goes as

$$E_{rot} = \frac{\hbar^2}{2I} l(l+1)$$

Going from $l = 5$ to $l = 4$ results in an energy change of

$$\Delta E = E_4 - E_5 = \frac{\hbar^2}{2I}4(4+1) - \frac{\hbar^2}{2I}5(5+1) = \frac{\hbar^2}{2I}20 - \frac{\hbar^2}{2I}30 = -\frac{\hbar^2}{2I}10$$

This loss of energy is an energy gain by the photon. The energy of a photon is given by

$$E = \frac{hc}{\lambda}$$

Set this equal to the energy lost by the molecule gives

$$\frac{\hbar^2}{2I}10 = \frac{hc}{\lambda}$$

Replace $\hbar$ with $h/2\pi$ and solving for wavelength gives

$$\frac{h^2}{8\pi^2 I}10 = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc8\pi^2 I}{10h^2} = \frac{4\pi^2 cI}{5h}$$

Substitute in the appropriate values gives

$$\lambda = \frac{4\pi^2(3.00 \times 10^8\ m/s)(1.75 \times 10^{-47}\ kg \cdot m^2)}{5(6.63 \times 10^{-34}\ J \cdot s)} = 6.25 \times 10^{-5}\ m = 62.5\ \mu m$$

† Problem from Essential University Physics, Wolfson