PLI #11
June 21, 2021

1. **Exposure to high doses of microwaves can cause tissue damage. Estimate how many photons, with λ=12cm, must be absorbed to raise the temperature of your eye by 3.5°C. Assume the mass of an eye is 11 g and its specific heat capacity is 4.0 J/g°C.**

First, find the amount of energy needed to raise the temperature of the eye:

$q=mc\Delta T= 11g * 4.01\frac{J}{g^{\circ}C} * 3.5^{\circ}C = 154.385\,J$

Next, find how much energy is in each photon:

$$E_{photon} = \frac{hc}{\lambda} = \frac{(6.626 * 10^{-34} J * s)\left(3.00 * 10^{8}\frac{m}{s}\right)}{0.12\,m} = 1.6565 * 10^{-24}\frac{J}{photon}$$

Combine to cancel joules and have photons remaining

$$154.385\,J * \frac{1\,photon}{1.6565 * 10^{-24} J} = 9.32 * 10^{25} photons$$

2. **Molybdenum metal must absorb radiation with a minimum frequency of $1.09x10^{15}$ s^{-1} before it can eject an electron from its surface via the photoelectric effect.**

a. **What is the minimum energy needed to eject an electron?**

$E_{min} = h\nu = (6.626 * 10^{-34} J * s)(1.09 * 10^{15} s^{-1}) = 7.22 * 10^{-19} J$

b. **What wavelength of radiation will provide a photon of this energy?**

$$E_{photon} = \frac{hc}{\lambda}$$

$7.22 * 10^{-19} J = (6.626 * 10^{-34:} J * s)* (3.00 * 10^{8} (m/s)$

$$7.22 * 10^{-19} J = \frac{(6.626 * 10^{-34} J * s)\left(3.00 * 10^{8}\frac{m}{s}\right)}{\lambda}$$

$$\lambda = 2.75 * 10^{-7} m$$

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3. **A diode laser emits at a wavelength of 987 nm. All of its output energy is absorbed in a detector that measures a total energy of 0.52 J over a period of 32 seconds. How many photons per second are being emitted by the laser?**

$$E_{photon} = \frac{hc}{\lambda} = \frac{(6.626 * 10^{-34} J * s)\left(3.00 * 10^{8} \frac{m}{s}\right)}{987 * 10^{-9}\, m} = 2.01 * 10^{-19} \frac{J}{photon}$$

$$\frac{0.52\ \mathrm{J}}{32\ s} * \frac{1\ photon}{2.01 * 10^{-19} J} = 8.07 * 10^{16} \frac{photon}{s}$$

4. **Suppose a microwave emits electromagnetic radiation with a wavelength of 11.2 cm. How many photons of radiation are required to heat 200. mL of coffee from 23 °C to 60°C? If the power of the microwave is 900. W (J/s), how long would it take to heat the coffee? (assume the specific heat and density of coffee are the same as water's).**

Calculate the # of joules needed to elevate the temperature of the coffee using q=mcΔT

ΔT = 60˚C-23˚C = 37˚C

q=(4.184 J/g) (200 g) (37°C)=30962 Joules

$E = \frac{nhc}{\lambda}$ (including number of photons required)

$n = \frac{E\lambda}{hc} = \frac{30962\ J * 0.112\ m}{6.626 * 10^{-34} J * s * 3.00 * 10^{8} (\frac{m}{s})} = 1.7 * 10^{28} photons$

Energy delivered is power x time, or E=w*t, so 30962 Joules = (900 Joules/second) * t

t=34 seconds

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5. What is the maximum number of orbitals (m_l) with:

6. **a. n=4 and l=1:** 3, m_l can be -1, 0, 1

   b. n=2 and l=2: 0! L can only range to n-1
   c. n=3 and l=2: 5, m_l can be -2, -1, 0, 1, 2
   d. n=5, l=2, and m_l=-1: 1, m_l being -1 specifies a single orbital

5. **What are the quantum numbers (n, l, and m_l) that can describe a 3p orbital?**

n=3,l=1,m_l=-1,0,1

6. **What are the quantum numbers that can describe a 5d orbital?**

n=5,l=2,m_l=-2,-1,0,1,2

7. **What is the maximum number of electrons that can occupy each of the following subshells? (Hint: each electron must have a unique set of quantum numbers)**

   a. 3p: 6

   b. 2s: 2

   c. 5d: 10

   d. 4f: 14