Introduction to QM  
Worksheet 1

1. The world famous KROQ radio station broadcasts at a frequency of $1.067 \times 10^8 \text{ s}^{-1}$ (106.7 MHz). Calculate the wavelength of the radio waves.

$$\lambda = \frac{c}{v} = \frac{(2.998 \times 10^8 \text{ m/s})}{(1.067 \times 10^8 \text{ s}^{-1})} = 2.810 \text{ m}$$

2. On August 18, 1977, Jerry Ehman detected a radio signal from outer space that resonated at 1420.4556 MHz. His explanation was: Wow! Jerry hypothesizes that this could be an alien signal from the constellation Sagittarius. Sagittarius is about $6.62 \times 10^{17} \text{ km}$ from the Earth. Calculate the wavelength of these alien signals. How long in years did this message take to reach Earth?

$$\lambda = \frac{c}{v} = \frac{(2.998 \times 10^8 \text{ m/s})}{(1.4204556 \times 10^9 \text{ s}^{-1})} = 0.2110 \text{ m}$$

Time = distance/rate = \((6.62 \times 10^{17} \text{ km})/(2.998 \times 10^5 \text{ km/s}) = 2.21 \times 10^{12} \text{ sec}
2.21 \times 10^{12} \text{ sec} = 70000 \text{ years}

3. A photic sneeze is a sneeze that results from the exposure to bright light. Photic sneezes are hypothesized to occur in response to light with a specific wavelength of 430 nm, which corresponds to the wavelength of a cloudless blue sky. Calculate the frequency of this sneeze causing light.

$$v = \frac{c}{\lambda} = \frac{(2.998 \times 10^8 \text{ m/s})}{(430 \times 10^{-9} \text{ m})} = 6.97 \times 10^{14} \text{ Hz}$$

4. Silver atoms in a flame emit light as they undergo transitions from one energy level to another that is $3.81 \times 10^{-19} \text{ J}$. Calculate the wavelength of light emitted and predict the color visible in the flame.

$$E = h \nu = h(c/\lambda)$$

$$\lambda = \frac{hc}{E} = \frac{(6.626 \times 10^{-34} \text{ J s})(2.998 \times 10^8 \text{ m/s})}{(3.81 \times 10^{-19} \text{ J})} = 5.21 \times 10^{-7} \text{ m}$$

5. A certain high-powered laser pointer has a power output of 150 mW and has a range of 60 miles. The green laser beam it produces has a wavelength of 532 nm. (a) Calculate the energy carried by each photon. (b) Calculate the number of photons emitted by the laser per second. (1 W = 1 J/s)

$$E = h \nu = h(c/\lambda) = (6.626 \times 10^{-34} \text{ J s})(2.998 \times 10^8 \text{ m/s})/(532 \times 10^{-9} \text{ m}) = 3.73 \times 10^{-19} \text{ J/photon}$$

$$150 \text{ mW} = 150 \times 10^{-3} W = 150 \times 10^{-3} \text{ J/s}$$

$$\text{photons/sec} = (150 \times 10^{-3} \text{ J/s})/(3.73 \times 10^{-19} \text{ J/photon}) = 4.02 \times 10^{17} \text{ photons/sec}$$
6. Use the Bohr model to calculate the radius and the energy of the $B^{4+}$ ion in the $n = 3$ state. How much energy would be required to remove the electrons from 1 mol of $B^{4+}$ in this state? What frequency and wavelength of light would be emitted in a transition form the $n = 3$ to the $n = 2$ state of this ion? Express all results in SI units.

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\begin{align*}
  r_n &= a_0 \left( \frac{n^2}{Z} \right) \\
  r_3 &= 5.29 \times 10^{-11} \text{ m} \left( \frac{3^2}{5} \right) = 9.52 \times 10^{-11} \text{ m} \\
  E_n &= -R_\infty \left( \frac{Z^2}{n^2} \right) \\
  E_3 &= -2.18 \times 10^{-18} \text{ J} \left( \frac{5^2}{3^2} \right) = -6.06 \times 10^{-18} \text{ J} \\
  \text{Energy to remove 1 mol of electrons} \\
  E &= \left( -6.06 \times 10^{-18} \text{ J/atom} \right) \times (6.022 \times 10^{23} \text{ atoms/mole}) = 3.56 \times 10^6 \text{ J/mol} \\
  n = 3 \rightarrow 2 \\
  \Delta E &= E_2 - E_3 = 2.18 \times 10^{-18} \text{ J} \left( -\frac{5^2}{2^2} + \frac{5^2}{3^2} \right) = -7.57 \times 10^{-18} \text{ J} \\
  \Delta E &= h\nu = hc/\lambda \\
  \nu &= \frac{h}{\Delta E} = \left( 6.626 \times 10^{-34} \text{ J s} \right) / \left( -7.57 \times 10^{-18} \text{ J} \right) = 1.14 \times 10^{16} \text{ Hz} \\
  \lambda &= \frac{hc}{\Delta E} = \left( 6.626 \times 10^{-34} \text{ J s} \right) \left( 2.998 \times 10^8 \text{ m/s} \right) / \left( -7.57 \times 10^{-18} \text{ J} \right) = 2.63 \times 10^{-8} \text{ m}
\end{align*}
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