Take-Home Assignment 02

Bohr's model for the hydrogen atom predicts that the wavelength of the photon emitted when an electron moves from an initial shell, n_i, to a final shell, n_f, is

$$\frac{1}{\lambda} = R \times \left\{ \frac{1}{n_f^2} - \frac{1}{n_i^2} \right\}$$

where n_f is less than n_i, and where R has a value of 1.09737×10^7 m^{-1}. We can extend this equation to any one-electron ion, such as He^+ or Li^{2+}, if we account for the charge on ion's nucleus, Z

$$\frac{1}{\lambda} = R \times Z^2 \times \left\{ \frac{1}{n_f^2} - \frac{1}{n_i^2} \right\}$$

What is the wavelength, in nanometers, of the photon that is emitted when the single electron in an ion of helium with a charge of +1 moves from the $n_i = 9$ shell to the $n_f = 8$ shell? What is the frequency of this photon in s^{-1} and its energy in J and in kJ/mol?

Solution

Plugging in 2 for the charge on the nucleus (note that Z is the charge on the nucleus, which is equal to the atomic number, not the charge of the ion), 9 for the initial shell, and 8 for the final shell gives the wavelength as 6947.09 nm. To calculate the frequency, we note that $c = \lambda\nu$ where c is the speed of light (2.998×10^8 m/s); thus, we obtain a frequency of 4.32e+13 s^{-1}. To calculate the energy in Joules, we note that $E = \mathrm{h}\nu$ where h is Planck's cosntant (6.626×10^{-34} Js), or 2.86e-20 J. To convert to an energy in kJ/mol, we multiply by Avogadro's number (6.022×10^{23} mol^{-1}) and divide by 1000 to convert J to kJ; thus, the energy is 17.2 kJ/mol.