41.3 • **CP** A photon is emitted when an electron in a three-dimensional box of side length 8.00×10^{-11} m makes a transition from the $n_X = 2, n_Y = 2, n_Z = 1$ state to the $n_X = 1, n_Y = 1, n_Z = 1$ state. What is the wavelength of this photon?

CUBIC BOX $E_{n_x, n_y, n_z} = (n_x^2 + n_y^2 + n_z^2)\left(\frac{h^2}{8mL^2}\right)$

$E_\gamma = \frac{hc}{\lambda} = E_{221} - E_{111} = [9-3]\left(\frac{h^2}{8mL^2}\right) = \frac{6(hc)^2}{8mc^2L^2}$

$hc = 1240$ eV nm

$mc^2 = 0.511$ MeV

$L = 8 \times 10^{-2}$ nm

$\lambda = \frac{4mc^2L^2}{3 \times hc} = \frac{0.511 \times 4 \times 10^{+6} \times 64 \times 10^{-4} \text{ eV nm}^2}{3 \times 1240 \text{ eV nm}}$

$\lambda = 3.5$ nm (X-RAY)

41.1 • For a particle in a three-dimensional box, what is the degeneracy (number of different quantum states with the same energy) of the following energy levels: (a) $3\pi^2\hbar^2/2mL^2$ and (b) $9\pi^2\hbar^2/2mL^2$?

$$E_{n_x,n_y,n_z} = (n_x^2 + n_y^2 + n_z^2)\left(\frac{h^2}{8mL^2}\right)$$

$$= (n_x^2 + n_y^2 + n_z^2)\left(\frac{4\pi^2\hbar^2}{8mL^2}\right) = (n_x^2 + n_y^2 + n_z^2)\left(\frac{\pi^2\hbar^2}{2mL^2}\right)$$

a) $E = 3(\cdot\cdot)$ $n_x^2 + n_y^2 + n_z^2 = 3 \rightarrow E_{111}$ NON-DEGENERATE 1 STATE $g = 1$

b) $E = 9(\cdot\cdot)$; $n_x^2 + n_y^2 + n_z^2 = 9$; E_{221}; $g = 3$ $\psi_{221}, \psi_{212}, \psi_{122}$

41.49 • Consider an electron in hydrogen having total energy −0.5440 eV. (a) What are the possible values of its orbital angular momentum (in terms of $\hbar$)? (b) What wavelength of light would it take to excite this electron to the next higher shell? Is this photon visible to humans?

$$E_n = -\frac{13.6\,\text{eV}}{n^2} = -0.5440\,\text{eV} \qquad n = \sqrt{\frac{13.6}{0.544}} \simeq \sqrt{25} = 5$$

$n \to l = 0, 1, 2, \ldots, n-1$; $n = 5$, $l = 0, 1, 2, 3, 4$

$L = \hbar\sqrt{l(l+1)}$ $\quad L/\hbar = 0, \sqrt{2}, \sqrt{6}, \sqrt{12}, \sqrt{20}$

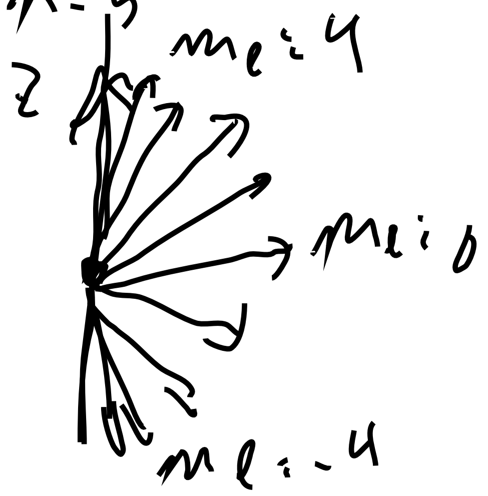
$$\frac{hc}{\lambda} = E_\gamma = E_6 - E_5 = 13.6\left(\frac{1}{25} - \frac{1}{36}\right)$$

$$\lambda = \frac{hc}{13.6\left(\frac{1}{25} - \frac{1}{36}\right)} = 7{,}460\,\text{nm} = 7.46\,\mu\text{m} \quad \text{IR}$$

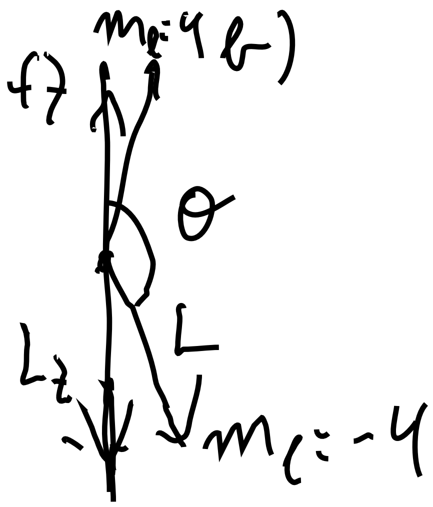
41.13 •• (a) How many different $5g$ states does hydrogen have? (b) Which of the states in part (a) has the largest angle between $\vec{L}$ and the z-axis, and what is that angle? (c) Which of the states in part (a) has the smallest angle between $\vec{L}$ and the z-axis, and what is that angle?

s, p, d, f, g
0 1 2 3 4

5g
↓ ↳ $l=4$
$n=5$



$m_l = -4, \ldots, 0, \ldots 4$



$2l+1 = 9$ count spin
9 states $2\times(2l+1)$ states
18 states

$\cos\theta = \frac{L_z}{L} = -\frac{4\hbar}{\sqrt{20}\,\hbar} = -\frac{4}{\sqrt{20}} = -\sqrt{\frac{4}{5}}$

$\theta_a = 153°$

$\cos\theta_b = \sqrt{\frac{4}{5}} \rightarrow \theta_b = 180-153 = 27°$

41.19 • A hydrogen atom in the 5*g* state is placed in a magnetic field of 0.600 T that is in the *z*-direction. (a) Into how many levels is this state split by the interaction of the atom's orbital magnetic dipole moment with the magnetic field? (b) What is the energy separation between adjacent levels? (c) What is the energy separation between the level of lowest energy and the level of highest energy? 5g → $l = 4$ $2l+1$ states a) 9 LEVELS → $E_{m_l} = m_l \mu_B B$

$m_l+1 \to m_l$ $\Delta E = \mu_B B = (5.79 \times 10^{-5}\ eV/T)\ 0.6\ T = 34.7\ \mu eV = 3.47 \times 10^{-5}\ eV$

$\mu_B = \frac{e\hbar}{2m} = 5.79 \times 10^{-5}\ eV/T$ $E_{m_l=4} - E_{m_l=-4} = 8\mu_B B = 2.78\ \mu eV =$

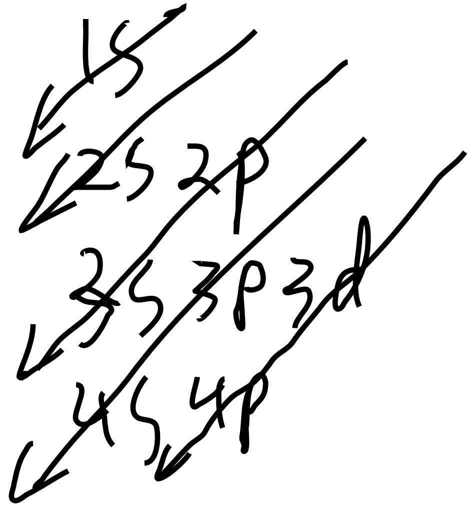
$= 8\Delta E$ $= 2.78 \times 10^{-4}\ eV$

$4\mu_B B - (-4\mu_B B) = 8\mu_B B$

41.28 •• (a) Write out the ground-state electron configuration ($1s^2$, $2s^2$, . . .) for the carbon atom. (b) What element of next-larger Z has chemical properties similar to those of carbon? Give the ground-state electron configuration for this element.

C → Z = 6 $1s^2 2s^2 2p^2$

2 2 2 = 6



$1s^2 2s^2 2p^6 3s^2 3p^2$

Z = 14 Si

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$ Z = 32   Ge