21. ***REASONING AND SOLUTION*** The de Broglie wavelength λ is given by Equation 29.8 as $\lambda = h/p$, where p is the magnitude of the momentum of the particle. The magnitude of the momentum is $p = mv$, where m is the mass and v is the speed of the particle. Using this expression in Equation 29.8, we find that

$$\lambda = \frac{h}{mv} \quad \text{or} \quad v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34}\ \text{J} \cdot \text{s}}{\left(1.67 \times 10^{-27}\ \text{kg}\right)\left(0.282 \times 10^{-9}\ \text{m}\right)} = \boxed{1.41 \times 10^{3}\ \text{m/s}}$$

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22. ***REASONING*** The de Broglie wavelength λ is related to Planck's constant h and the magnitude p of the particle's momentum. The magnitude of the momentum is related to the mass m and the speed v at which the bacterium is moving. Since the mass and the speed are given, we can calculate the wavelength directly.

SOLUTION The de Broglie wavelength is

$$\lambda = \frac{h}{p} \tag{29.8}$$

The magnitude of the momentum is $p = mv$ (Equation 7.2), which we can substitute into Equation 29.8 to show that the de Broglie wavelength of the bacterium is

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63\times10^{-34}\ \text{J}\cdot\text{s}}{\left(2\times10^{-15}\ \text{kg}\right)\left(0.33\ \text{m/s}\right)} = \boxed{1\times10^{-18}\ \text{m}}$$

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9. **_REASONING_** The atomic number for helium is $Z = 2$. The ground state is the $n = 1$ state, the first excited state is the $n = 2$ state, and the second excited state is the $n = 3$ state. With
$Z = 2$ and $n = 3$, we can use Equation 30.10 to find the radius of the ion.

SOLUTION The radius of the second excited state is

$$r_3 = \left(5.29\times10^{-11}\text{ m}\right)\frac{n^2}{Z} = \left(5.29\times10^{-11}\text{ m}\right)\frac{3^2}{2} = \boxed{2.38\times10^{-10}\text{ m}} \qquad (30.10)$$

---

11. **SSM** ***REASONING*** According to Equation 30.14, the wavelength λ emitted by the hydrogen atom when it makes a transition from the level with n_i to the level with n_f is given by

$$\frac{1}{\lambda}=\frac{2\pi^2 mk^2e^4}{h^3c}\,(Z^2)\left(\frac{1}{n_\text{f}^2}-\frac{1}{n_\text{i}^2}\right)\quad \text{with}\quad n_\text{i}, n_\text{f}=1,\ 2,\ 3,\ldots\quad\text{and}\quad n_\text{i}>n_\text{f}$$

where $2\pi^2mk^2e^4/(h^3c)=1.097\times10^7\ \text{m}^{-1}$ and $Z = 1$ for hydrogen. Once the wavelength for the particular transition in question is determined, Equation 29.2 ($E=hf=hc/\lambda$) can be used to find the energy of the emitted photon.

SOLUTION In the Paschen series, $n_\text{f} = 3$. Using the above expression with $Z = 1$, $n_\text{i} = 7$ and $n_\text{f} = 3$, we find that

$$\frac{1}{\lambda}=\left(1.097\times10^7\ \text{m}^{-1}\right)\left(1^2\right)\left(\frac{1}{3^2}-\frac{1}{7^2}\right)\qquad\text{or}\qquad \lambda=1.005\times10^{-6}\ \text{m}$$

The photon energy is

$$E=\frac{hc}{\lambda}=\frac{\left(6.63\times10^{-34}\ \text{J}\cdot\text{s}\right)\left(3.00\times10^8\ \text{m/s}\right)}{1.005\times10^{-6}\ \text{m}}=\boxed{1.98\times10^{-19}\ \text{J}}$$

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12. ***REASONING*** Since the atom emits two photons as it returns to the ground state, one is emitted when the electron falls from $n = 3$ to $n = 2$, and the other is emitted when it subsequently drops from $n = 2$ to $n = 1$. The wavelengths of the photons emitted during these transitions are given by Equation 30.14 with the appropriate values for the initial and final numbers, n_i and n_f.

SOLUTION The wavelengths of the photons are

n = 3 to n = 2

$$\frac{1}{\lambda}=\left(1.097\times10^{7}\ \text{m}^{-1}\right)(1)^{2}\left(\frac{1}{2^{2}}-\frac{1}{3^{2}}\right)=1.524\times10^{6}\ \text{m}^{-1} \qquad (30.14)$$

$$\lambda=\boxed{6.56\times10^{-7}\ \text{m}}$$

n = 2 to n = 1

$$\frac{1}{\lambda}=\left(1.097\times10^{7}\ \text{m}^{-1}\right)(1)^{2}\left(\frac{1}{1^{2}}-\frac{1}{2^{2}}\right)=8.228\times10^{6}\ \text{m}^{-1} \qquad (30.14)$$

$$\lambda=\boxed{1.22\times10^{-7}\ \text{m}}$$

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21. ***REASONING*** The orbital quantum number ℓ has values of 0, 1, 2, ..., $(n - 1)$, according to the discussion in Section 30.5. Since $\ell = 5$, we can conclude, therefore, that $n \geq 6$. This knowledge about the principal quantum number n can be used with Equation 30.13,
$E_n = -(13.6\text{ eV})Z^2/n^2$, to determine the smallest value for the total energy E_n.

SOLUTION The smallest value of E_n (i.e., the most negative) occurs when $n = 6$. Thus, using $Z = 1$ for hydrogen, we find

$$E_n = -(13.6\text{ eV})\frac{Z^2}{n^2} = -(13.6\text{ eV})\frac{1^2}{6^2} = \boxed{-0.378\text{ eV}}$$

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23. **SSM** **WWW** ***REASONING*** The values that ℓ can have depend on the value of n, and only the following integers are allowed: $\ell = 0,\ 1,\ 2,\ \ldots\ (n-1)$. The values that m_ℓ can have depend on the value of ℓ, with only the following positive and negative integers being permitted: $m_\ell = -\ell,\ \ldots -2, -1, 0, +1, +2, \ldots +\ell$.

SOLUTION Thus, when $n = 6$, the possible values of ℓ are $0,\ 1,\ 2,\ 3,\ 4,\ 5$. Now when $m_\ell = 2$, the possible values of ℓ are $2,\ 3,\ 4,\ 5,\ \ldots$ These two series of integers overlap for the integers 2, 3, 4, and 5. Therefore, the possible values for the orbital quantum number ℓ that this electron could have are $\boxed{\ell = 2,\ 3,\ 4,\ 5}$.

29. ***REASONING AND SOLUTION*** According to Figure 30.17, the energy sublevel with $n = 4$, $\ell = 0$, which corresponds to the notation $4\mathrm{s}$, is lower in energy than the $n = 3$, $\ell = 2$, ($3\mathrm{d}$) energy sublevel. Thus, the $4\mathrm{s}$ energy sublevel will be filled before the $3\mathrm{d}$ energy sublevel. Therefore, using Figure 30.17 as a guide, we find that the ground state electronic configuration of arsenic ($Z = 33$) is

$$\boxed{1\mathrm{s}^2\ 2\mathrm{s}^2\ 2\mathrm{p}^6\ 3\mathrm{s}^2\ 3\mathrm{p}^6\ 4\mathrm{s}^2\ 3\mathrm{d}^{10}\ 4\mathrm{p}^3}$$

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33. $\boxed{\textbf{SSM}}$ ***REASONING*** This problem is similar to Example 11 in the text. We use Equation 30.14 with the initial value of n being $n_{\mathrm{i}} = 2$, and the final value being $n_{\mathrm{f}} = 1$. As in Example 11, we use a value of Z that is one less than the atomic number of the atom in question (in this case, a value of $Z = 41$ rather than 42); this accounts approximately for the shielding effect of the single K-shell electron in canceling out the attraction of one nuclear proton.

SOLUTION Using Equation 30.14, we obtain

$$\frac{1}{\lambda} = (1.097\times10^{7}\ \mathrm{m}^{-1})(41)^{2}\left(\frac{1}{1^{2}} - \frac{1}{2^{2}}\right) \qquad \text{or} \qquad \boxed{\lambda = 7.230\times10^{-11}\ \mathrm{m}}$$

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35. ***REASONING*** The wavelength λ of a photon is $\lambda = c/f$, according to Equation 16.1, where f is the frequency and c is the speed of light in a vacuum. The frequency is given by Equation 29.2 as $f = E/h$, where E is the energy of the Bremsstrahlung photon and h is Planck's constant. Substituting this expression for f into the expression for the wavelength gives

$$\lambda = \frac{c}{f} = \frac{c}{E/h} = \frac{hc}{E}$$

The energy of the photon is 35.0% of the kinetic energy KE of the electron that collides with the metal target. According to our discussions in Section 19.2, the electron acquires its kinetic energy by accelerating from rest through a potential difference V, the kinetic energy being KE = eV, where e is the magnitude of the charge on the electron. Thus, we have that $E = 0.350$ KE $= 0.350\ eV$. Substituting this result into the wavelength expression shows that

$$\lambda = \frac{hc}{E} = \frac{hc}{0.350\,eV} \tag{1}$$

SOLUTION Using Equation (1), we find that

$$\lambda = \frac{hc}{0.350\,eV} = \frac{\left(6.63\times10^{-34}\ \text{J}\cdot\text{s}\right)\left(3.00\times10^{8}\ \text{m/s}\right)}{0.350\left(1.60\times10^{-19}\ \text{C}\right)\left(52.0\times10^{3}\ \text{V}\right)} = \boxed{6.83\times10^{-11}\ \text{m}}$$