3. Strategy The energy of a photon of EM radiation with frequency f is $E = hf$. The frequency and wavelength are related by $\lambda f = c$.

Solution

(a) Calculate the wavelength of a photon with energy 3.1 eV.

$$E = hf = \frac{hc}{\lambda}, \text{ so } \lambda = \frac{hc}{E} = \frac{1240 \text{ eV}\cdot\text{nm}}{3.1 \text{ eV}} = \boxed{400 \text{ nm}}.$$

(b) Calculate the frequency of a photon with energy 3.1 eV.

$$f = \frac{c}{\lambda} = \frac{3.00\times10^{8} \text{ m/s}}{400\times10^{-9} \text{ m}} = \boxed{7.5\times10^{14} \text{ Hz}}$$

6. (a) Strategy The threshold wavelength is $\lambda_0 = 288$ nm. The threshold wavelength is related to the threshold frequency by $\lambda_0 f_0 = c$. The work function is given by Eq. (27-8).

Solution Find the work function.

$$\phi = hf_0 = \frac{hc}{\lambda_0} = \frac{1240 \text{ eV}\cdot\text{nm}}{288 \text{ nm}} = \boxed{4.31 \text{ eV}}$$

(b) Strategy Use Einstein's photoelectric equation.

Solution Calculate the maximum kinetic energy.

$$K_{\text{max}} = hf - \phi = \frac{hc}{\lambda} - \phi = \frac{1240 \text{ eV}\cdot\text{nm}}{140 \text{ nm}} - 4.306 \text{ eV} = \boxed{4.6 \text{ eV}}$$

36. Strategy The amount of energy required to cause a transition from the ground state to the $n = 4$ state is equal to the difference in the energy between the two states. The energy for a hydrogen atom in the nth stationary state is given by $E_n = (-13.6 \text{ eV})/n^2$.

Solution The energy of a hydrogen atom in the $n = 4$ state is

$$E_4 = \frac{E_1}{4^2} = \frac{-13.6 \text{ eV}}{16} = -0.850 \text{ eV}.$$

The energy that must be supplied is $E_4 - E_1 = -0.850 \text{ eV} - (-13.6 \text{ eV}) = \boxed{12.8 \text{ eV}}$.

40. Strategy The minimum energy for an ionized atom is $E_{\text{ionized}} = 0$. Use Eq. (27-24).

Solution The energy needed to ionize a hydrogen atom initially in the $n = 2$ state is

$$E = E_{\text{ionized}} - E_2 = E_{\text{ionized}} - \frac{E_1}{2^2} = 0 - \left(\frac{-13.6 \text{ eV}}{4}\right) = \boxed{3.40 \text{ eV}}.$$

2. Strategy Find the de Broglie wavelength using Eq. (28-1). Compare the result to the size of a proton.

Solution

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.626\times10^{-34}\ \text{J}\cdot\text{s}}{(1.0\times10^{-4}\ \text{kg})(2\times10^{-3}\ \text{m/s})} = \boxed{3\times10^{-27}\ \text{m}}$$

The ratio of the size of λ to a proton is $\frac{3\times10^{-27}\ \text{m}}{1\times10^{-15}\ \text{m}} = 3\times10^{-12}$.

The size of $\boxed{\text{the wavelength is about } 3\times10^{-12} \text{ times the size of a proton}}$.

3. Strategy Set the de Broglie wavelength of the student equal to the width of the door and use $p = mv$. Then use $\Delta x = v\Delta t$ to find the time it would take the student to walk through the doorway.

Solution

(a) Find the speed required for the student to exhibit diffraction.

$$\lambda = \frac{h}{p} = \frac{h}{mv},\ \text{so}\ v = \frac{h}{m\lambda} = \frac{6.626\times10^{-34}\ \text{J}\cdot\text{s}}{(81\ \text{kg})(0.81\ \text{m})} = \boxed{1.0\times10^{-35}\ \text{m/s}}.$$

(b) At this speed, it would take the student $\Delta t = \frac{\Delta x}{v} = \frac{0.12\ \text{m}}{1.0\times10^{-35}\ \text{m/s}}\times\frac{1\ \text{yr}}{3.156\times10^{7}\ \text{s}} = \boxed{3.8\times10^{26}\ \text{yr}}$ to walk through the doorway.

5.Strategy The electron's kinetic energy is small compared to its rest energy, so the electron is nonrelativistic and we can use $p = mv$ and $K = \frac{1}{2}mv^2$ to find the momentum. Find the de Broglie wavelength using Eq. (28-1) and the wavelength of the photon using $E = hc/\lambda$.

Solution First solve for p in terms of K.

$$K = \frac{1}{2}mv^2,\ \text{so}\ v = \sqrt{\frac{2K}{m}}.$$

The momentum is then $p = mv = m\sqrt{\frac{2K}{m}} = \sqrt{2Km}$.

Find the de Broglie wavelength of the electron.

$$\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2Km_e}}$$

The wavelength of a photon is $\lambda_p = \frac{hc}{E_p}$. Compute the ratio of the wavelengths.

$$\frac{\lambda_p}{\lambda_e} = \frac{hc/E_p}{h/\sqrt{2Km}} = \frac{c\sqrt{2Km}}{E_p} = \frac{(3.00\times10^{8}\ \text{m/s})\sqrt{2(0.100\times10^{3}\ \text{eV})(1.602\times10^{-19}\ \text{J/eV})(9.109\times10^{-31}\ \text{kg})}}{(0.100\times10^{3}\ \text{eV})(1.602\times10^{-19}\ \text{J/eV})} = \boxed{101}$$

4.Strategy The nucleon number A is the sum of the total number of protons Z and neutrons N. Use the Periodic Table of the elements to identify the element.

Solution Identify the element.
Z = # of protons = 38; the element is Sr.
N = # of neutrons = 50
Find the nucleon number.
$A = Z + N = 38 + 50 = 88$
So, the symbol is $\boxed{{}^{88}_{38}\text{Sr}}$.

21.Strategy In beta-minus decay, the atomic number Z increases by 1 while the mass number A remains constant. Use Eq. (29-11).

Solution

For the parent $\left({}^{40}_{19}\text{K}\right)$ $Z = 19$, so the daughter nuclide will have $Z = 19 + 1 = 20$, which is the element Ca. The symbol for the daughter is $\boxed{{}^{40}_{20}\text{Ca}}$.

33.Strategy The activity is reduced by a factor of two for each half-life. Use Eqs. (29-18), (29-20), and (29-22) to find the initial number of nuclei and the probability of decay per second.

Solution

(a) Find the number of half-lives.

$$600.0\text{ s} = \frac{600.0\text{ s}}{200.0\text{ s/half-life}} = 3.000\text{ half-lives}$$

The activity after 3.000 half-lives will be $R = \left(\frac{1}{2}\right)^{3.000} \times R_0 = \frac{1}{8.000} \times 80{,}000.0\text{ s}^{-1} = \boxed{10{,}000\text{ s}^{-1}}$.

(b) Find the initial number of nuclei.

$$N_0 = \frac{1}{\lambda}R_0 = \tau R_0 = \frac{R_0 T_{1/2}}{\ln 2} = 80{,}000.0\text{ s}^{-1} \times \frac{200.0\text{ s}}{\ln 2} = \boxed{2.308 \times 10^7}$$

(c) The probability per second is $\lambda = \frac{1}{\tau} = \frac{\ln 2}{T_{1/2}} = \frac{\ln 2}{200.0\text{ s}} = \boxed{3.466 \times 10^{-3}\text{ s}^{-1}}$.

36.Strategy The activity as a function of time is given by $R = R_0 e^{-t/\tau}$. Use Eq. (29-22) to find the time constant.

Solution Find the number of days for the activity to decrease to 2.5×10^6 Bq.

$$e^{-t/\tau} = \frac{R}{R_0},\text{ so } -\frac{t}{\tau} = \ln\frac{R}{R_0} \text{ or } t = -\tau \ln\frac{R}{R_0} = -\frac{8.0\text{ d}}{\ln 2} \times \ln\frac{2.5 \times 10^6\text{ Bq}}{6.4 \times 10^8\text{ Bq}} = \boxed{64\text{ d}}.$$

46.(a) Strategy The absorbed dose of ionizing radiation is the amount of radiation energy absorbed per unit mass of tissue. The number of photons that must be absorbed is equal to the total energy absorbed divided by the energy per photon.

Solution Calculate the energy absorbed.

$$\frac{\text{energy }(E)}{\text{mass }(m)} = \text{absorbed dose}$$

$$E = m(\text{absorbed dose}) = 0.30\text{ kg} \times 2000.0\text{ Gy} = 600\text{ J}$$

Calculate the number of photons.

$$\#\text{ of photons} = \frac{\text{total energy }(E)}{\text{energy per photon}} = \frac{600\text{ J} \cdot \frac{1\text{ eV}}{1.602 \times 10^{-19}\text{ J}}}{100.0 \times 10^3\text{ eV/photon}} = \boxed{3.7 \times 10^{16}\text{ photons}}$$

(b) Strategy Use Eq. (14-4).

Solution Find the temperature increase.

$$Q = mc\Delta T,\ \text{so}\ \Delta T = \frac{Q}{mc} = \frac{600\ \text{J}}{0.30\ \text{kg} \times 4186\ \text{J/(kg}\cdot\text{K)}} = \boxed{0.48°\text{C}}.$$

70.(a) Strategy Use the percent abundance of potassium-40 in the potassium in the broccoli and the atomic masses to find the mass of the potassium-40 in the broccoli. The number of nuclei is related to the mass by $N = mN_\text{A}/M$, where N_A is Avogadro's number and M is the molar mass.

Solution Find the mass of potassium-40.

$$\frac{m_{40}}{m} = \frac{N_{40}M_{40}/N_\text{A}}{NM/N_\text{A}} = \frac{N_{40}}{N} \times \frac{M_{40}}{M},\ \text{so}$$

$$m_{40} = \frac{N_{40}}{N} \times \frac{M_{40}}{M} m = (0.000117)\frac{39.963\,998\,7}{39.0983}(0.000\,30\ \text{kg}) = \boxed{3.6 \times 10^{-8}\ \text{kg}}.$$

(b) Strategy The activity is related to the number of nuclei N and the time constant τ by $R = N/\tau$. The number of nuclei is related to the mass by $N = mN_\text{A}/M$, where N_A is Avogadro's number and M is the molar mass. The time constant is related to the half-life by $T_{1/2} = \tau \ln 2$.

Solution Compute the activity.

$$R = \frac{N}{\tau} = \frac{mN_\text{A} \ln 2}{MT_{1/2}} = \frac{(3.6 \times 10^{-5}\ \text{g})(6.022 \times 10^{23}\ \text{mol}^{-1}) \ln 2}{(39.963\,998\,7\ \text{g/mol})(1.248 \times 10^{9}\ \text{yr})(3.156 \times 10^{7}\ \text{s/yr})} = \boxed{9.5\ \text{Bq}}$$