spectrum is this absorption found? (b) Determine the initial and final values of n associated with this absorption.

6.33 Use the de Broglie relationship to determine the wavelengths of the following objects: (a) an 85-kg person skiing at 50 km/hr; (b) a 10.0-g bullet fired at 250 m/s; (c) a lithium atom moving at 2.5×10^5 m/s.

6.34 Among the elementary subatomic particles of physics is the muon, which decays within a few nanoseconds after formation. The muon has a rest mass 206.8 times that of an electron. Calculate the de Broglie wavelength associated with a muon traveling at a velocity of 8.85×10^5 cm/s.

6.35 Neutron diffraction is an important technique for determining the structures of molecules. Calculate the velocity of a neutron that has a characteristic wavelength of 0.955 Å. (Refer to the back inside cover for the mass of the neutron.)

6.36 The electron microscope has been widely used to obtain highly magnified images of biological and other types of materials. When an electron is accelerated through a particular potential field, it attains a speed of 5.93×10^6 m/s. What is the characteristic wavelength of this electron? Is the wavelength comparable to the size of atoms?

6.37 Using Heisenberg's uncertainty principle, calculate the uncertainty in the position of (a) a 1.50-mg mosquito moving at a speed of 1.40 m/s if the speed is known to within ± 0.01 m/s; (b) a proton moving at a speed of $(5.00 \pm 0.01) \times 10^4$ m/s. (The mass of a proton is given in the table of fundamental constants in the back inside cover of the text.)

6.38 Calculate the uncertainty in the position of (a) an electron moving at a speed of $(3.00 \pm 0.01) \times 10^5$ m/s; (b) a neutron moving at this same speed. (The masses of an electron and a neutron are given in the table of fundamental constants in the back inside cover of the text.) (c) What are the implications of these calculations to our model of the atom?

Quantum Mechanics and Atomic Orbitals

6.39 According to the Bohr model, an electron in the ground state of a hydrogen atom orbits the nucleus at a specific radius of 0.53 Å. In the quantum mechanical description of the hydrogen atom, the most probable distance of the electron from the nucleus is 0.53 Å. Why are these two statements different?

6.40 (a) In the quantum mechanical description of the hydrogen atom, what is the physical significance of the square of the wave function, ψ^2? (b) What is meant by the expression "electron density"? (c) What is an orbital?

6.41 (a) For $n = 4$, what are the possible values of l? (b) For $l = 2$, what are the possible values of m_l?

6.42 How many possible values for l and m_l are there when (a) $n = 3$; (b) $n = 5$?

6.43 Give the numerical values of n and l corresponding to each of the following designations: (a) $3p$; (b) $2s$; (c) $4f$; (d) $5d$.

6.44 Give the values for n, l, and m_l for (a) each orbital in the $2p$ subshell; (b) each orbital in the $5d$ subshell.

6.45 Which of the following represent impossible combinations of n and l: (a) $1p$, (b) $4s$; (c) $5f$; (d) $2d$?

6.46 Which of the following are permissible sets of quantum numbers for an electron in a hydrogen atom: (a) $n = 2, l = 1, m_l = 1$; (b) $n = 1, l = 0, m_l = -1$; (c) $n = 4, l = 2, m_l = -2$; (d) $n = 3, l = 3, m_l = 0$? For those combinations that are permissible, write the appropriate designation for the subshell to which the orbital belongs (that is, $1s$, and so on).

6.47 Sketch the shape and orientation of the following types of orbitals: (a) s; (b) p_z; (c) d_{xy}.

6.48 Sketch the shape and orientation of the following types of orbitals: (a) p_x; (b) d_{z^2}; (c) $d_{x^2-y^2}$.

6.49 (a) What are the similarities and differences between the hydrogen atom $1s$ and $2s$ orbitals? (b) In what sense does a $2p$ orbital have *directional character*? Compare the "directional" characteristics of the p_x and $d_{x^2-y^2}$ orbitals (that is, in what direction or region of space is the electron density concentrated?). (c) What can you say about the average distance from the nucleus of an electron in a $2s$ orbital as compared with a $3s$ orbital? (d) For the hydrogen atom, list the following orbitals in order of increasing energy (that is, most stable ones first): $4f$, $6s$, $3d$, $1s$, $2p$.

6.50 (a) With reference to Figure 6.18, what is the relationship between the number of nodes in an s orbital and the value of the principal quantum number? (b) Identify the number of nodes; that is, identify places where the electron density is zero, in the $2p_x$ orbital; in the $3s$ orbital. (c) The nodes in s orbitals are spherical surfaces (Figure 6.18). What kind of surface do you expect the nodes to be in the p orbitals (Figure 6.20)? (d) For the hydrogen atom, list the following orbitals in order of increasing energy: $3s$, $2s$, $2p$, $5s$, $4d$.

Many-Electron Atoms and Electron Configurations

6.51 For a given value of the principal quantum number, n, how do the energies of the s, p, d, and f subshells vary for (a) hydrogen; (b) a many-electron atom?

6.52 (a) The average distance from the nucleus of a $3s$ electron in a chlorine atom is smaller than that for a $3p$ electron. In light of this fact, which orbital is higher in energy? (b) Would you expect it to require more or less energy to remove a $3s$ electron from the chlorine atom, as compared with a $2p$ electron? Explain.

6.53 (a) What are the possible values of the electron spin quantum number? (b) What piece of experimental equipment can be used to distinguish electrons that have different values of the electron spin quantum number? **(c)** Two electrons in an atom both occupy the 1*s* orbital. What quantity must be different for the two electrons? What principle governs the answer to this question?

6.54 **(a)** State the Pauli exclusion principle in your own words. **(b)** The Pauli exclusion principle is, in an important sense, the key to understanding the periodic table. Explain why.

6.55 What is the maximum number of electrons that can occupy each of the following subshells: **(a)** 3*d*; **(b)** 4*s*; **(c)** 2*p*; **(d)** 5*f*?

6.56 What is the maximum number of electrons in an atom that can have the following quantum numbers: **(a)** $n = 2, m_s = -\frac{1}{2}$; **(b)** $n = 5, l = 3$; **(c)** $n = 4, l = 3, m_l = -3$; **(d)** $n = 4, l = 1, m_l = 1$.

6.57 **(a)** What does each box in an orbital diagram represent? **(b)** What quantity is represented by the direction (either up or down) of the half arrows in an orbital diagram? **(c)** Is Hund's rule needed to write the electron configuration of beryllium? Explain.

6.58 **(a)** What are "outer-shell electrons"? **(b)** What are "unpaired electrons"? **(c)** How many outer-shell electrons does an Si atom possess? How many of these are unpaired?

6.59 Write the condensed electron configurations for the following atoms, using the appropriate noble-gas core abbreviations: **(a)** Cs; **(b)** Ni; **(c)** Se; **(d)** Cd; **(e)** Ac; **(f)** Pb.

6.60 Write the condensed electron configurations for the following atoms: **(a)** Al; **(b)** Sc; **(c)** Co; **(d)** Br; **(e)** Ba **(f)** Re; **(g)** Lu.

6.61 Draw the orbital diagrams for the valence electrons of each of the following elements, and indicate how many unpaired electrons each has: **(a)** S; **(b)** Sr; **(c)** Fe; **(d)** Zr; **(e)** Sb; **(f)** U.

6.62 Using orbital diagrams, determine the number of unpaired electrons in each of the following atoms: **(a)** Ti; **(b)** Ga; **(c)** Rh; **(d)** I; **(e)** Po.

6.63 Identify the specific element that corresponds to each of the following electron configurations: **(a)** $1s^22s^22p^63s^2$; **(b)** $[Ne]3s^23p^1$; **(c)** $[Ar]4s^13d^5$; **(d)** $[Kr]5s^24d^{10}5p^4$.

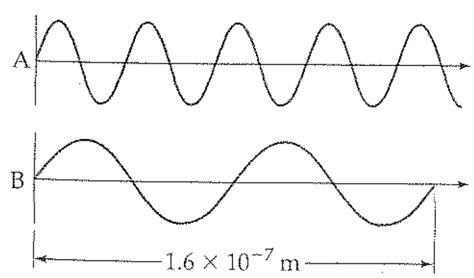
6.64 Identify the group of elements that corresponds to each of the following generalized electron configurations:
(a) [noble gas] ns^2np^5
(b) [noble gas] $ns^2(n-1)d^2$
(c) [noble gas] $ns^2(n-1)d^{10}np^1$
(d) [noble gas] $ns^2(n-2)f^6$

6.65 What is wrong with the following electron configurations for atoms in their ground states? **(a)** $1s^22s^23s^1$; **(b)** $[Ne]2s^22p^3$; **(c)** $[Ne]3s^23d^5$.

6.66 The following electron configurations represent excited states. Identify the element and write its ground-state condensed electron configuration. **(a)** $1s^22s^23p^24p^1$; **(b)** $[Ar]3d^{10}4s^14p^45s^1$; **(c)** $[Kr]4d^65s^25p^1$.

Additional Exercises

6.67 Consider the two waves shown here, which we will consider to represent two electromagnetic radiations:



(a) What is the wavelength of wave A? Of wave B? **(b)** What is the frequency of wave A? Of wave B? **(c)** Identify the regions of the electromagnetic spectrum to which waves A and B belong.

6.68 Certain elements emit light of a specific wavelength when they are burned. Historically, chemists used such emission wavelengths to determine whether specific elements were present in a sample. Some characteristic wavelengths for some of the elements are

Ag	328.1 nm	Fe	372.0 nm
Au	267.6 nm	K	404.7 nm
Ba	455.4 nm	Mg	285.2 nm
Ca	422.7 nm	Na	589.6 nm
Cu	324.8 nm	Ni	341.5 nm

(a) Determine which elements emit radiation in the visible part of the spectrum. **(b)** Which element emits photons of highest energy? Of lowest energy? **(c)** When burned, a sample of an unknown substance is found to emit light of frequency $6.59 \times 10^{14}\ s^{-1}$. Which of these elements is probably in the sample?

6.69 Images of Ganymede, Jupiter's largest moon, were transmitted from *Galileo*, the unmanned spacecraft, when its distance from Earth was 522 million miles. How long did it take for the transmitted signals to travel from the spacecraft to Earth?

6.70 The rays of the Sun that cause tanning and burning are in the ultraviolet portion of the electromagnetic spectrum. These rays are categorized by wavelength: So-called UV-A radiation has wavelengths in the range of 320–380 nm, whereas UV-B radiation has wavelengths in the range of 290–320 nm. **(a)** Calculate the frequency of light that has a wavelength of 320 nm. **(b)** Calculate the energy of a mole of 320-nm photons. **(c)** Which are more energetic, photons of UV-A radiation or photons of UV-B radiation? **(d)** The UV-B radiation from the Sun is considered a greater cause of sunburn in humans than is UV-A radiation. Is this observation consistent with your answer to part (c)?

6.71 The watt is the derived SI unit of power, the measure of energy per unit time: 1 W = 1 J/s. A semiconductor laser in a CD player has an output wavelength of 780 nm and a power level of 0.10 mW. How many photons strike the CD surface during the playing of a CD 69 minutes in length?

6.72 Carotenoids, present in all organisms capable of photosynthesis, extend the range of light absorbed by the organism. They exhibit maximal capacity for absorption of light in the range of 440–470 nm. Calculate the energy represented by absorption of an Avogadro's number of photons of wavelength 455 nm.