27–8 Wave Nature of Matter

37. (I) Calculate the wavelength of a 0.23-kg ball traveling at 0.10 m/s.

38. (I) What is the wavelength of a neutron $(m = 1.67 \times 10^{-27}\,\text{kg})$ traveling at $6.5 \times 10^4\,\text{m/s}$?

39. (I) Through how many volts of potential difference must an electron be accelerated to achieve a wavelength of 0.24 nm?

40. (II) Calculate the ratio of the kinetic energy of an electron to that of a proton if their wavelengths are equal. Assume that the speeds are nonrelativistic.

41. (II) An electron has a de Broglie wavelength $\lambda = 5.0 \times 10^{-10}\,\text{m}$. (*a*) What is its momentum? (*b*) What is its speed? (*c*) What voltage was needed to accelerate it to this speed?

42. (II) What is the wavelength of an electron of energy (*a*) 10 eV, (*b*) 100 eV, (*c*) 1.0 keV?

43. (II) Show that if an electron and a proton have the same nonrelativistic kinetic energy, the proton has the shorter wavelength.

44. (II) Calculate the de Broglie wavelength of an electron in your TV picture tube if it is accelerated by 30,000 V. Is it relativistic? How does its wavelength compare to the size of the "neck" of the tube, typically 5 cm? Do we have to worry about diffraction problems blurring our picture on the screen?

45. (III) A Ferrari with a mass of 1400 kg approaches a freeway underpass that is 10 m across. At what speed must the car be moving, in order for it to have a wavelength such that it might somehow "diffract" after passing through this "single slit"? How do these conditions compare to normal freeway speeds of 30 m/s?

* 27–9 Electron Microscope

* **46.** (II) What voltage is needed to produce electron wavelengths of 0.20 nm? (Assume that the electrons are nonrelativistic.)

* **47.** (II) Electrons are accelerated by 2450 V in an electron microscope. What is the maximum possible resolution?

27–12 Bohr Model

48. (I) For the three hydrogen transitions indicated below, with n being the initial state and n' being the final state, is the transition an absorption or an emission? Which is higher, the initial state energy or the final state energy of the atom? Finally, which of these transitions involves the largest energy photon? (*a*) $n = 1,\; n' = 3$ (*b*) $n = 6,\; n' = 2$ (*c*) $n = 4,\; n' = 5$.

49. (I) How much energy is needed to ionize a hydrogen atom in the $n = 2$ state?

50. (I) The third longest wavelength in the Paschen series in hydrogen (Fig. 27–27) corresponds to what transition?

51. (I) Calculate the ionization energy of doubly ionized lithium, Li^{2+}, which has $Z = 3$.

52. (I) (*a*) Determine the wavelength of the second Balmer line ($n = 4$ to $n = 2$ transition) using Fig. 27–27. Determine likewise (*b*) the wavelength of the second Lyman line and (*c*) the wavelength of the third Balmer line.

53. (I) Evaluate the Rydberg constant R using Bohr theory (compare Eqs. 27–9 and 27–16) and show that its value is $R = 1.0974 \times 10^7\,\text{m}^{-1}$.

54. (II) What is the longest wavelength light capable of ionizing a hydrogen atom in the ground state?

55. (II) What wavelength photon would be required to ionize a hydrogen atom in the ground state and give the ejected electron a kinetic energy of 10.0 eV?

56. (II) In the Sun, an ionized helium (He^+) atom makes a transition from the $n = 6$ state to the $n = 2$ state, emitting a photon. Can that photon be absorbed by hydrogen atoms present in the Sun? If so, between what energy states will the hydrogen atom jump?

57. (II) Construct the energy-level diagram for the He^+ ion (see Fig. 27–27).

58. (II) Construct the energy-level diagram for doubly ionized lithium, Li^{2+}.

59. (II) What is the potential energy and the kinetic energy of an electron in the ground state of the hydrogen atom?

60. (II) An excited hydrogen atom could, in principle, have a radius of 1.00 mm. What would be the value of n for a Bohr orbit of this size? What would its energy be?

61. (II) Is the use of nonrelativistic formulas justified in the Bohr atom? To check, calculate the electron's velocity, v, in terms of c, for the ground state of hydrogen, and then calculate $\sqrt{1 - v^2/c^2}$.

62. (III) Suppose an electron was bound to a proton, as in the hydrogen atom, but by the gravitational force rather than by the electric force. What would be the radius, and energy, of the first Bohr orbit?

27–13 de Broglie's Hypothesis Applied to Atoms

63. (III) Suppose a particle of mass m is confined to a one-dimensional box of width L. According to quantum theory, the particle's wave (with $\lambda = h/mv$) is a standing wave with nodes at the edges of the box. (*a*) Show the possible modes of vibration on a diagram. (*b*) Show that the kinetic energy of the particle has quantized energies given by $\text{KE} = n^2h^2/8mL^2$, where n is an integer. (*c*) Calculate the ground-state energy $(n = 1)$ for an electron confined to a box of width $0.50 \times 10^{-10}\,\text{m}$. (*d*) What is the ground-state energy, and speed, of a baseball $(m = 140\,\text{g})$ in a box 0.50 m wide? (*e*) An electron confined to a box has a ground-state energy of 22 eV. What is the width of the box?

General Problems

64. The Big Bang theory states that the beginning of the universe was accompanied by a huge burst of photons. Those photons are still present today and make up the so-called cosmic microwave background radiation. The universe radiates like a blackbody with a temperature of about 2.7 K. Calculate the peak wavelength of this radiation.

65. At low temperatures, nearly all the atoms in hydrogen gas will be in the ground state. What minimum frequency photon is needed if the photoelectric effect is to be observed?

66. A beam of 85-eV electrons is scattered from a crystal, as in X-ray diffraction, and a first-order peak is observed at $\theta = 38°$. What is the spacing between planes in the diffracting crystal? (See Section 25–11.)

67. A microwave oven produces electromagnetic radiation at $\lambda = 12.2\,\text{cm}$ and produces a power of 760 W. Calculate the number of microwave photons produced by the microwave oven each second.