24. Why do we expect electron transitions deep within an atom to produce shorter wavelengths than transitions by outer electrons?

* **25.** Compare spontaneous emission to stimulated emission.

* **26.** How does laser light differ from ordinary light? How is it the same?

* **27.** Explain how a 0.0005-W laser beam, photographed at a distance, can seem much stronger than a 1000-W street lamp at the same distance.

* **28.** Does the intensity of light from a laser fall off as the inverse square of the distance? Explain.

Problems

28–2 Wave Function, Double-Slit

1. (II) The neutrons in a parallel beam, each having kinetic energy $\frac{1}{40}$ eV, are directed through two slits 0.50 mm apart. How far apart will the interference peaks be on a screen 1.0 m away? [*Hint*: first find the wavelength of the neutron.]

2. (II) Bullets of mass 3.0 g are fired in parallel paths with speeds of 220 m/s through a hole 3.0 mm in diameter. How far from the hole must you be to detect a 1.0-cm-diameter spread in the beam of bullets?

28–3 Uncertainty Principle

3. (I) A proton is traveling with a speed of $(6.560 \pm 0.012) \times 10^5$ m/s. With what maximum accuracy can its position be ascertained? [*Hint*: $\Delta p = m\,\Delta v$.]

4. (I) If an electron's position can be measured to an accuracy of 2.0×10^{-8} m, how accurately can its speed be known?

5. (I) An electron remains in an excited state of an atom for typically 10^{-8} s. What is the minimum uncertainty in the energy of the state (in eV)?

6. (I) The Z^0 boson, discovered in 1985, is the mediator of the weak nuclear force, and it typically decays very quickly. Its average rest energy is 91.19 GeV, but its short lifetime shows up as an intrinsic width of 2.5 GeV (rest energy uncertainty). What is the lifetime of this particle?

7. (II) What is the uncertainty in the mass of a muon $(m = 105.7\ \text{MeV}/c^2)$, specified in eV/c^2, given its lifetime of 2.20 μs? [*Hint*: $\Delta E \approx \hbar/\Delta t$.]

8. (II) A free neutron $(m = 1.67 \times 10^{-27}\ \text{kg})$ has a mean life of 900 s. What is the uncertainty in its mass (in kg)?

9. (II) An electron and a 140-g baseball are each traveling 150 m/s measured to an accuracy of 0.055%. Calculate and compare the uncertainty in position of each.

10. (III) Estimate the lowest possible energy of a neutron contained in a typical nucleus of radius 1.0×10^{-15} m. [*Hint*: a particle can have an energy at least as large as its uncertainty.]

11. (III) Use the uncertainty principle to show that if an electron were present in the nucleus $(r \approx 10^{-15} m)$, its kinetic energy (use relativity) would be hundreds of MeV. (Since such electron energies are not observed, we conclude that electrons are not present in the nucleus.) [*Hint*: a particle can have an energy at least as large as its uncertainty.]

12. (III) How accurately can the position of a 3.00-keV electron be measured assuming its energy is known to 1.00%?

28–6 to 28–8 Quantum Numbers, Exclusion Principle

13. (I) For $n = 6$, what values can l have?

14. (I) For $n = 5$, $l = 3$, what are the possible values of m_l and m_s?

15. (I) How many electrons can be in the $n = 6$, $l = 3$ subshell?

16. (I) How many different states are possible for an electron whose principal quantum number is $n = 4$? Write down the quantum numbers for each state.

17. (I) List the quantum numbers for each electron in the ground state of (*a*) carbon ($Z = 6$), (*b*) magnesium ($Z = 12$).

18. (I) List the quantum numbers for each electron in the ground state of nitrogen ($Z = 7$).

19. (I) Suppose a certain hydrogen atom has $l = 4$. What are the possible values for n, m_l, and m_s?

20. (I) Calculate the magnitude of the angular momentum of an electron in the $n = 4$, $l = 3$ state of hydrogen.

21. (II) If a hydrogen atom has $m_l = -3$, what are the possible values of n, l, and m_s?

22. (II) Show that there can be 18 electrons in a "g" subshell.

23. (II) What is the full electron configuration in the ground state for elements with Z equal to (*a*) 27, (*b*) 36, (*c*) 38? [*Hint*: see the periodic table inside the back cover.]

24. (II) What is the full electron configuration for (*a*) selenium (Se), (*b*) gold (Au), (*c*) radium (Ra)? [*Hint*: see the periodic table inside the back cover.]

25. (II) A hydrogen atom is in the 6s state. Determine (*a*) the principal quantum number, (*b*) the energy of the state, (*c*) the orbital angular momentum and its quantum number l, and (*d*) the possible values for the magnetic quantum number.

26. (II) Estimate the binding energy of the third electron in lithium using the Bohr theory. [*Hint*: this electron has $n = 2$ and "sees" a net charge of approximately $+1e$.] The measured value is 5.36 eV.

27. (II) Show that the total angular momentum is zero for a filled subshell.

* **28.** (II) For each of the following atomic transitions, state whether the transition is *allowed* or *forbidden*, and if forbidden, what rule is being violated: (*a*) $4p \rightarrow 3p$; (*b*) $2p \rightarrow 1s$; (*c*) $3d \rightarrow 2d$; (*d*) $4d \rightarrow 3s$; (*e*) $4s \rightarrow 2p$.