CHAPTER 19 Review

REFLECTING ON CHAPTER 19

- Dalton believed that atoms were the smallest, indivisible particles in nature. J.J. Thomson demonstrated that electrons could be removed from atoms and, therefore, that atoms were made up of smaller particles.
- By observing the scattering of alpha particles by a thin gold foil, Rutherford demonstrated that the positive charge in an atom must be condensed into an extremely small area at the centre of the atom.
- Bohr proposed that electrons in atoms could exist only in specific allowed energy levels. Electrons in these energy levels are in orbits with specific allowed radii.
- The energies of the photons in the observed spectra of atomic hydrogen have amounts of energy that are exactly equal to the difference in Bohr's allowed energy levels. This fact supports Bohr's concept that electrons can drop from a high energy level to a lower level by emitting a photon.
- Detailed inspection of emission spectra of gases showed that some of the spectral lines are actually made up of two or more lines that are very close together. Also, when placed in an external magnetic field, some single spectral lines split into two or more lines. These data show that Bohr's model of the atom is incomplete.
- Schrödinger's wave equation forms the foundation of quantum mechanics, or wave mechanics. Solutions to the wave equation, called "wave functions," provide information about the properties of electrons in an atom. The operation, $\psi^*\psi$ on the wave function gives the probability that an electron will be found at a specific point in space.
- Dirac modified Schrödinger's wave equation to account for relativistic effects of electrons in atoms travelling close to the speed of light. Wave functions obtained by solving this wave equation contain four quantum numbers. Each quantum number describes one property of electrons that is quantized.
- The Pauli exclusion principle states that no two electrons in the same atom can have the same four quantum numbers.

Knowledge/Understanding

1. **(a)** What property of electromagnetic radiation represented a flaw in the Rutherford model of the atom?
(b) Balmer's equation represents an "empirical expression." What is the significance of this term?

2. In what way did Rydberg modify Balmer's equation?

3. **(a)** Describe the key features of the Bohr model of the atom, and indicate how this model contradicts classical theory.
(b) When electrons occupy a higher energy level, what are they likely to do? What options do they have?

4. **(a)** Write the equation linking the energy of a photon emitted from the Bohr atom to the energy levels of the atom.
(b) How does this manifest itself in the emission spectrum of an atom?

5. **(a)** According to Bohr, what property of the electron in its orbit is quantized?
(b) In general terms, explain how Bohr used the equations for Coulomb's law, circular motion, and angular momentum to determine the "Bohr radius."

6. **(a)** Describe how Bohr used the equations for kinetic energy, Coulomb's law, and the Bohr radius to determine the general formula for the total energy of an electron in a hydrogen atom.

(b) Explain how the Bohr equation for the total energy of an electron in orbit in a hydrogen atom relates to the observed emission spectrum.

7. **(a)** Show that the speed of an electron as it moves in an "allowed" orbit can be represented by the equation

$$v_n = \frac{2\pi k e^2}{nh}$$

(b) Calculate the de Broglie wavelength associated with an electron in the first orbit of the Bohr atom.

8. Schrödinger responded to de Broglie's thesis by developing the Schrödinger wave equation. In what general way did this equation account for the discrepancies in the emission spectra?

9. **(a)** Do you feel Schrödinger's wave equation is just an abstract model, or is there a "real" significance?
(b) Discuss whether you believe that the Schrödinger wave functions made the Bohr model obsolete.

Inquiry

10. Schrödinger's wave equation was a famous contribution to what is now called "quantum mechanics." At your library or through the Internet, find and record the exact text of the equation and describe, in general terms, the mathematical operations it incorporated.

11. **(a)** Research and describe the principle of complementarity.
(b) Under what conditions does light tend to show its wave properties, and under what conditions does the particle (photon) nature of light predominate?

Communication

12. Briefly outline the key features of the model of the atom proposed by John Dalton, J.J. Thomson, and Ernest Rutherford.

13. Based on the results of the scattering experiments, Rutherford was led to believe that the atom was mainly empty space with a small charged core. Explain why he deduced this.

Making Connections

14. Do library or Internet research to learn about the way that neon lights function. Write a summary explaining how an understanding of the Bohr model was necessary for the development of neon lights.

15. When P.A.M. Dirac adapted the wave equation to account for relativistic effects, the solutions to the equation implied that electrons have a property called "spin" and that new particles existed that Dirac called antielectrons. Both concepts were entirely new and the idea of antielectrons, now called positrons, was bizarre. Today, both electron spin and the existence of positrons are not only accepted, they have both been put to practical use. A research tool called electron spin resonance spectroscopy (ESR) — sometimes called electron paramagnetic resonance spectroscopy (EPR) — is commonly used by chemists, biochemists, and biophysicists. Do research to learn about the applications of ESR. What types of information have been obtained with the use of ESR?

Problems for Understanding

16. **(a)** Calculate the radius of the third orbit of an electron in the hydrogen atom.
(b) What is the energy level of the electron in the above orbit?

17. Calculate the wavelength of the second line in the Balmer series.

18. A photon of light is absorbed by a hydrogen atom in which the electron is already in the second energy level. The electron is lifted to the fifth energy level.
(a) What was the frequency of the absorbed photon?
(b) What was its wavelength?
(c) What is the total energy of the electron in the fifth energy level?
(d) Calculate the radius of the orbit representing the fifth energy orbit.
(e) If the electron subsequently returns to the first energy level in one "jump," calculate the wavelength of the corresponding photon to be emitted.