Pearson

Chapter Summary and Review

Key Learning Outcomes

CHAPTER OBJECTIVES	ASSESSMENT
Relate the Wavelength and Frequency of Light (2.2)	• Example 2.1 For Practice 2.1 Exercises 39, 40
Calculate the Energy of a Photon (2.2)	• Example 2.2 For Practice 2.2 For More Practice 2.2 Exercises 41, 42, 43, 44, 45, 46
Relate Wavelength, Energy, and Frequency to the Electromagnetic Spectrum (2.2)	• Example 2.3 For Practice 2.3 Exercises 37, 38
Use the de Broglie Relation to Calculate Wavelength (2.4)	• Example 2.4 For Practice 2.4 Exercises 49, 50, 51, 52, 53, 54
Relate Quantum Numbers to One Another and to Their Corresponding Orbitals (2.5)	• Examples 2.5, 2.6 For Practice 2.5, 2.6 Exercises 59, 60, 61, 62
Relate the Wavelength of Light to Transitions in the Hydrogen Atom (2.5)	• Example 2.7 For Practice 2.7 For More Practice 2.7 Exercises 69, 70, 71, 72

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Key Terms

Section 2.1

quantum-mechanical model

Section 2.2

electromagnetic radiation
amplitude
wavelength (λ)
frequency (ν)
electromagnetic spectrum
gamma ray
X-ray
ultraviolet (UV) radiation
visible light
infrared (IR) radiation

infrared (IR) radiation
microwave
radio wave
interference
constructive interference
destructive interference
diffraction
photoelectric effect
binding energy
photon (quantum)

Section 2.3

emission spectrum
absorption spectrum

Section 2.4

de Broglie relation
complementary properties
Heisenberg's uncertainty principle
deterministic
indeterminacy

Section 2.5

orbital
wave function (ψ)
quantum number
principal quantum number (n)
angular momentum quantum number (l)
magnetic quantum number (m_l)
spin quantum number (m_s)
electron spin
principal level (shell)
sublevel (subshell)

Section 2.6

probability density
radial distribution function
node
phase

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Key Concepts

The Realm of Quantum Mechanics (2.1)

- The theory of quantum mechanics explains the behavior of absolutely small particles, such as electrons, in the atomic and subatomic realms.
- These particles behave differently than the sorts of particles we see in the macroscopic world.

The Nature of Light (2.2)

- Light is a type of electromagnetic radiation—a form of energy embodied in oscillating electric and magnetic fields that travels though space at 3.00×10^8 m/s.
- The wave nature of light is characterized by its wavelength—the distance between wave crests—and its ability to experience interference (constructive or destructive) and diffraction.

- The electromagnetic spectrum includes all wavelengths of electromagnetic radiation from gamma rays (high energy per photon, short wavelength) to radio waves (low energy per photon, long wavelength). Visible light is a tiny sliver in the middle of the electromagnetic spectrum.
- The particle nature of light is characterized by the specific quantity of energy carried in each photon.

Atomic Spectroscopy (2.3)

- Atomic spectroscopy is the study of the light absorbed and emitted by atoms when an electron makes a transition from one energy level to another.
- The wavelengths absorbed or emitted depend on the energy differences between the levels involved in the transition; large energy differences result in short wavelengths, and small energy differences result in long wavelengths.

The Wave Nature of Matter (2.4)

- Electrons have a wave nature with an associated wavelength, as quantified by the de Broglie relation.
- The wave nature and particle nature of matter are complementary—the more we know of one, the less we know of the other.
- The wave–particle duality of electrons is quantified in Heisenberg's uncertainty principle, which states that there is a limit to how well we can know both the position of an electron (associated with the electron's particle nature) and the velocity times the mass of an electron (associated with the electron's wave nature)—the more accurately one is measured, the greater the uncertainty in measurement of the other.
- The inability to simultaneously know both the position and the velocity of an electron results in indeterminacy, the inability to predict a trajectory for an electron. Consequently, electron behavior is described differently than the behavior of everyday-sized particles.
- The trajectory we normally associate with macroscopic objects is replaced, for electrons, with statistical descriptions that show, not the electron's path, but the region where it is most likely to be found.

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The Quantum-Mechanical Model of the Atom (2.5, 2.6)

- The most common way to describe electrons in atoms according to quantum mechanics is to solve the Schrödinger equation for the energy states of the electrons within the atom. When the electron is in these states, its energy is well defined but its position is not. The position of an electron is described by a probability distribution map called an orbital.
- The solutions to the Schrödinger equation (including the energies and orbitals) are characterized by quantum numbers: n, l and m_l.
- The principal quantum number (n) determines the energy of the electron and the size of the orbital; the angular momentum quantum number (l) determines the shape of the orbital; the magnetic quantum number (m_l) determines the orientation of the orbital. A fourth quantum number, the spin quantum number (m_s), specifies the orientation of the spin of the electron.

Key Equations and Relationships

Relationship between Frequency (ν), Wavelength (λ), and the Speed of Light (c) (2.2)

$$\nu = \frac{c}{\lambda}$$

Relationship between Energy (E), Frequency (ν), Wavelength (λ), and Planck's Constant (h) (2.2)

$$\begin{aligned} E &= hv \\ E &= \frac{hc}{\lambda} \end{aligned}$$

de Broglie Relation: Relationship between Wavelength (λ), Mass (m), and Velocity (v) of a Particle (2.4)

$$\lambda = \frac{h}{mv}$$

Heisenberg's Uncertainty Principle: Relationship between a Particle's Uncertainty in Position (Δx) and Uncertainty in Velocity (Δv) (2.4)

$$\Delta x \times m\Delta v \geq \frac{h}{4\pi}$$

Energy of an Electron in an Orbital with Quantum Number n in a Hydrogen Atom (2.5)

$$E_n = -2.18 \times 10^{-18}\ \mathrm{J}\left(\frac{1}{n^2}\right)\ (n = 1, 2, 3, \ldots)$$

Change in Energy That Occurs in an Atom When It Undergoes a Transition between Levels n_{initial} and n_{final} (2.5)

$$\Delta E = -2.18 \times 10^{-18}\ \mathrm{J}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

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