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5 ELECTRONS IN ATOMS

SECTION 5.1 MODELS OF THE ATOM (pages 127–132)

This section summarizes the development of atomic theory. It also explains the significance of quantized energies of electrons as they relate to the quantum mechanical model of the atom.

▶ The Development of Atomic Models (pages 127–128)

1. Complete the table about atomic models and the scientists who developed them.

Scientist	Model of Atom
Dalton	The atom is a solid indivisible mass.
Thomson	The atom is a ball of positive charge with electrons stuck into the ball.
Rutherford	Most of an atom's mass is concentrated in the small, positively charged nucleus. The electrons surround the nucleus and the rest of the atom is empty space.
Bohr	Electrons are arranged in concentric circular paths around the nucleus.

2. Is the following sentence true or false? The electrons in an atom can exist between energy levels. ____false____

▶ The Bohr Model (pages 128–129)

3. What is a small, discrete unit of energy called?

It is called a quantum.

4. Circle the letter of the term that completes the sentence correctly. A quantum of energy is the amount of energy required to

a. move an electron from its present energy level to the next lower one

b. maintain an electron in its present energy level

(c.) move an electron from its present energy level to the next higher one

5. In general, the higher the electron is on the energy ladder, the ____farther____ it is from the nucleus.

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CHAPTER 5, Electrons in Atoms *(continued)*

▶ The Quantum Mechanical Model (page 130)

6. What is the difference between the previous models of the atom and the modern quantum mechanical model? Previous models described the motion of electrons the same way as the motion of large objects. The quantum mechanical model is not based on the exact path an electron follows around the nucleus.

7. Is the following sentence true or false? The quantum mechanical model of the atom estimates the probability of finding an electron in a certain position.

true

▶ Atomic Orbitals (pages 131–132)

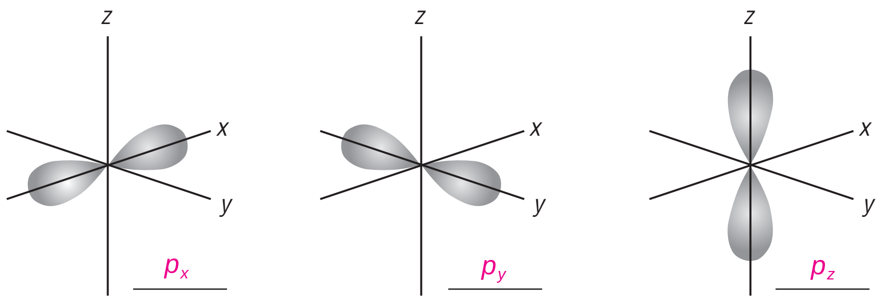
8. Circle the letter of the term that correctly answers this question. Which name describes the major energy levels of electrons?

a. atomic orbitals
b. quantum mechanical numbers
c. quantas
(d.) principal quantum numbers (n)

9. Principal energy levels are assigned values in order of generally increasing energy: $n = 1, 2, 3, 4$, and so forth.

10. In the quantum mechanical model the regions where electrons are likely to be found are called atomic orbitals and are denoted by letters.

11. Match each diagram below with the name of its p orbital, the p_x, p_y, or p_z.



p orbitals

12. Use the diagram above. Describe how the p_x, p_y, and p_z orbitals are similar.
The *p* orbitals are similar because they are all dumbbell shaped.

13. Describe how the p_x, p_y, and p_z orbitals are different. The *p* orbitals have different orientations in space. They are all perpendicular to each other.

14. Circle the letter of the formula for the maximum number of electrons that can occupy a principal energy level. Use n for the principal quantum number.

(a.) $2n^2$ **b.** n^2 **c.** $2n$ **d.** n

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SECTION 5.2 ELECTRON ARRANGEMENT IN ATOMS (pages 133–136)

This section shows you how to apply the aufbau principle, the Pauli exclusion principle, and Hund's rule to help you write the electron configurations of elements. It also explains why the electron configurations for some elements differ from those assigned using the aufbau principle.

▶ Electron Configurations (pages 133–135)

1. The ways in which electrons are arranged around the nuclei of atoms are called ___electron configurations___ .

Match the name of the rule used to find the electron configurations of atoms with the rule itself.

___b___ **2.** aufbau principle

___c___ **3.** Pauli exclusion principle

___a___ **4.** Hund's rule

a. When electrons occupy orbitals of equal energy, one electron enters each orbital until all the orbitals contain one electron with parallel spins.

b. Electrons enter orbitals of lowest energy first.

c. An atomic orbital may describe at most two electrons.

5. Look at the aufbau diagram, Figure 5.7 on page 133. Which atomic orbital is of higher energy, a 4*f* or a 5*p* orbital? ___4f___

6. Fill in the electron configurations for the elements given in the table. Use the orbital filling diagrams to complete the table.

Electron Configurations for Some Selected Elements

Element	Orbital filling 1*s*	2*s*	$2p_x$	$2p_y$	$2p_z$	3*s*	Electron configuration
H	↑						$1s^1$
He	↑↓						$1s^2$
Li	↑↓	↑					$1s^22s^1$
C	↑↓	↑↓	↑	↑			$1s^22s^22p^2$
N	↑↓	↑↓	↑	↑	↑		$1s^22s^22p^3$
O	↑↓	↑↓	↑↓	↑	↑		$1s^22s^22p^4$
F	↑↓	↑↓	↑↓	↑↓	↑		$1s^22s^22p^5$
Ne	↑↓	↑↓	↑↓	↑↓	↑↓		$1s^22s^22p^6$
Na	↑↓	↑↓	↑↓	↑↓	↑↓	↑	$1s^22s^22p^63s^1$

7. In the shorthand method for writing an electron configuration, what does a superscript stand for?

   The superscript stands for the number of electrons occupying a given sublevel.

8. In the shorthand method for writing an electron configuration, what does the sum of the superscripts equal?

   The sum equals the number of electrons in the atom.

▶ Exceptional Electron Configurations (page 136)

9. Is the following sentence true or false? The aufbau principle works for every element in the periodic table. ____false____

10. Filled energy sublevels are more ____stable____ than partially filled sublevels.

11. Half-filled levels are not as stable as ____filled____ levels, but are more stable than other configurations.

Reading Skill Practice

Outlining can help you understand and remember what you have read. Prepare an outline of Section 5.2, *Electron Arrangement in Atoms.* Begin your outline by copying the headings from the textbook. Under each heading, write the main idea. Then list the details that support, or back up, the main idea. Do your work on a separate sheet of paper.

The subheads of students' outlines of the section should be Electron Configurations and Exceptional Electron Configurations. The section's main ideas should form the next level of the outline.

SECTION 5.3 PHYSICS AND THE QUANTUM MECHANICAL MODEL (pages 138–146)

This section explains how to calculate the wavelength, frequency, or energy of light, given two of these values. It also explains the origin of the atomic emission spectrum of an element.

▶ Light (pages 138–140)

1. Match each term describing waves to its definition.

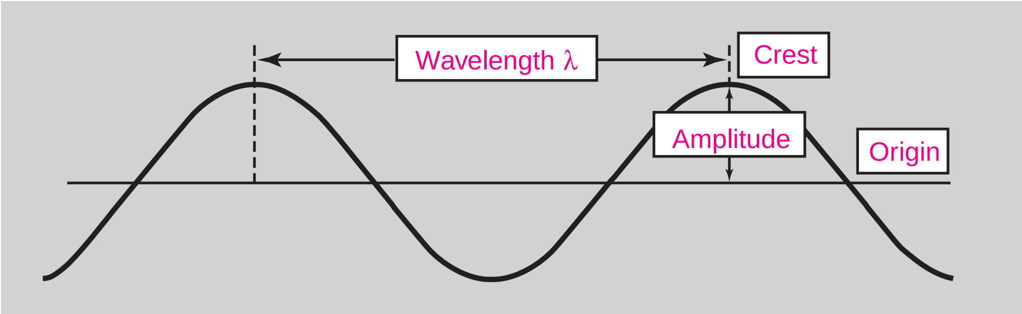
   ____b____ amplitude — **a.** the distance between two crests

   ____a____ wavelength — **b.** the wave's height from the origin to the crest

   ____c____ frequency — **c.** the number of wave cycles to pass a given point per unit of time

2. The units of frequency are usually cycles per second. The SI unit of cycles per second is called a(n) hertz (Hz) .

3. Label the parts of a wave in this drawing. Label the wavelength, the amplitude, the crest, and the origin.



4. The product of wavelength and frequency always equals a(n) constant , the speed of light.

5. Is the following sentence true or false? The wavelength and frequency of all waves are inversely proportional to each other. true

6. Light consists of electromagnetic waves. What kinds of visible and invisible radiation are included in the electromagnetic spectrum?

The following kinds of radiation are included in the electromagnetic spectrum: radio waves, microwaves, infrared waves, visible light, ultraviolet waves, x-ray, and gamma rays.

7. When sunlight passes through a prism, the different wavelengths separate into a(n) spectrum of colors.

8. Put the visible colors in order of frequency.

2 orange	6 violet
4 green	3 yellow
5 blue	1 red

9. Look at Figure 5.10 on page 139. The electromagnetic spectrum consists of radiation over a broad band of wavelengths. What type of radiation has the lowest frequency? The highest frequency?

Radio waves have the lowest frequency. Gamma rays have the highest frequency.

▶ Atomic Spectra (page 141)

10. What happens when an electric current is passed through the gas or vapor of an element?

The element emits light as it is excited by the passage of the electric current.

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11. Passing the light emitted by an element through a prism gives the atomic emission spectrum of the element.

12. Is the following sentence true or false? The emission spectrum of an element can be the same as the emission spectrum of another element.

false

▶ An Explanation of Atomic Spectra (pages 142–143)

13. What is the lowest possible energy of an electron called? ground state

14. Only electrons moving from higher to lower energy levels lose energy and emit light.

▶ Quantum Mechanics (pages 381–382)

15. What did Albert Einstein call the quanta of energy that is light?

photons

16. What did de Broglie's equation predict about the behavior of particles?

It predicts that all moving objects have wavelike motions.

17. Is the following sentence true or false? The new method of describing the motions of subatomic particles, atoms, and molecules is called quantum mechanics. true

18. Is the following sentence true or false? de Broglie's conclusions were supported by experimental evidence. true

19. Does the Heisenberg uncertainty principle apply to cars and airplanes?

No, only to small particles.

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GUIDED PRACTICE PROBLEM

GUIDED PRACTICE PROBLEM 14 (page 140)

14. What is the wavelength of radiation with a frequency of 1.50×10^{13} Hz ($1.50 \times 10^{13}\ s^{-1}$)? Does this radiation have a longer or shorter wavelength than red light?

Analyze

Step 1. What is the equation for the relationship between frequency and wavelength? $c = \lambda\upsilon$

Step 2. What does *c* represent and what is its value?

It represents the speed of light, which is 3.00×10^8 m/s.

Step 3. What is the wavelength of red light in cm?

Red light has a wavelength of about 700 nm, which can be converted to m by dividing by 10^9 nm/m, producing 7×10^{-7} m.

Solve

Step 4. Solve the equation for the unknown. $\lambda = \frac{c}{\upsilon}$

Step 5. Substitute the known quantities into the equation and solve.

$$\frac{3.00 \times 10^8\ \text{m/s}}{1.50 \times 10^{13}\ \text{s}} = 2.00 \times 10^{-5}\ \text{m}$$

Step 6. Compare the answer with the wavelength of red light. Does the given radiation have a wavelength longer or shorter than that of red light?

The answer, 2.00×10^{-5} m, is greater than the wavelength of red light, 7×10^{-7} m. Therefore, this radiation has a longer wavelength than red light.

Evaluate

Step 7. Explain why you think your result makes sense?

The magnitude of the frequency is about 10^5 times the magnitude of *c*. Because frequency and wavelength are inversely proportional to each other, the answer should be about 10^{-5}.

Step 8. Are the units in your answer correct? How do you know?

Yes, because wavelength is measured in meters or fractions of a meter.