Chapter 13 – Electrons in Atoms

Chapter 13: 1 – 20, 23 – 25, 27, 31, 32, 34 – 38, 41, 45, 47, 48, 52

Section 13.1 – Models of the Atom

Section Review 13.1

1. List in chronological order, a major contribution of each of these scientists to the understanding of the atom:

Dalton – proposed that all elements are composed of atoms.

Thomson – discovered electrons, developed plum pudding model.

Bohr – quantized energies of electrons, explaining why they don't fall into nucleus.

Schrodinger – developed the quantum mechanical model.

Rutherford – gold-foil experiment; discovered massive, positively-charged nucleus.

2. In general terms, explain how the quantum mechanical model of the atom describes the electronic structure of an atom.

The quantum mechanical model states that electrons have only fixed energy levels. Electrons are located in orbitals that may be visualized as clouds of various shapes at different distances from the nucleus.

3. The energies of electrons are said to be quantized. Explain what this means.

In an atom, electrons can only exist in certain fixed levels. To move from one energy level to another requires the emission or absorption of an exact amount of energy, or quantum.

4. How many orbitals are in the following sublevels?

a. *3p* sublevel __3__ b. *2s* sublevel __1__ c. *4f* sublevel __7__

d. *4p* sublevel __3__ e. *3d* sublevel __5__

Section 13.2 – Electron Arrangement in Atoms

Practice Problems

5. Write the complete electron configuration for each atom.

a. carbon $1s^2 2s^2 2p^2$ b. argon $1s^2 2s^2 2p^6 3s^2 3p^6$

6. Write the electron configuration for each atom. How many unpaired electrons does each atom have (electrons residing in orbitals by themselves)?

a. boron $1s^2 2s^2 2p^1$ 1 e^- b. silicon $1s^2 2s^2 2p^6 3s^2 3p^2$ 2 e^-

Section Review 13.2

7. Write the complete electron configuration for each atom.

a. lithium $1s^2 2s^1$ b. fluorine $1s^2 2s^2 2p^5$

c. rubidium $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$

8. Explain why the actual electron configurations for chromium and copper differ from those assigned using the aufbau diagram.

Electrons enter orbital of lowest energy first; half-filled energy sublevels are more stable than partially filled sublevels.

9. Arrange the following sublevels in order of decreasing energy: 2p, 4s, 3s, 3d, and 3p.

3d, 4s, 3p, 3s, 2p

10. Why does one electron in a potassium atom go into the fourth energy level instead of squeezing into the third energy level along with the eight already there?

The 3s and 3p orbitals are already filled; therefore the last electron must go into the next energy sublevel, which is 4s.

Section 13.3 – Physics and the Quantum Mechanical Model

Practice Problems

11. What is the wavelength of radiation with a frequency of 1.50×10^{13} s^{-1}? Does this radiation have a longer or shorter wavelength than red light?

Use $c = \lambda v$; rearrange to $\lambda = c/v$:

$\lambda = 3.00 \times 10^{10}$ cm/ s/ $1.50 \times 10^{13} s^{-1}$ = 0.002 cm, or 2×10^{-5} m; this has a longer wavelength than red light.

12. What frequency is radiation with a wavelength of 5.00×10^{-6} cm? In what region of the electromagnetic spectrum is this radiation?

Use $c = \lambda v$; rearrange to $v = c/\lambda$:

$v = 3.00 \times 10^{10}$cm/ s/ 5.00×10^{-6}cm; $v = 6.00 \times 10^{15} s^{-1}$

13. What is the energy of a photon of microwave radiation with a frequency of 3.20×10^{11} s^{-1}?

Use $E = hv$

$E = (6.6262\ x\ 10^{-34} J \cdot s)(3.2\ x\ 10^{11} s^{-1}) = 2.12\ x\ 10^{-22} J$

14. The threshold photoelectric effect in tungsten is produced by light of wavelength 260 nm. Give the energy of a photon of this light in joules.

First calculate the frequency of the light, using c = λv, rearrange to v = c/ λ

$$v = \left(\frac{3.00 \; x \; 10^{10} cm/\,s}{260 \; nm}\right)\left(\frac{1 \; x \; 10^{-7} nm}{1 \; cm}\right) = 1.15 \; x \; 10^{-9}/\,s$$

Then plug the frequency value in E = hv:

$$(E = 6.6262 \; x \; 10^{-34} J \cdot s)(1.15 \; x \; 10^{-9} s^{-1}) = 7.62 \; x \; 10^{-43} J$$

Section Review 13.3

15. A hydrogen lamp emits several lines in the visible region of the spectrum. One of these lines has a wavelength of 6.56 x 10^{-5} cm. What are the color and frequency of this radiation?

The color of this light is orange-red, with a frequency of 4.57 x $10^{14} s^{-1}$

16. Explain the origin of the atomic emission spectrum of an element.

Electrons in an atom absorb energy, then lose the energy and emit it as light.

17. Can classical physics explain the photoelectric effect? Explain your answer.

No. Metals eject electrons when certain wavelengths of light shine on them. Classical physics would assume *any* wavelength of light could cause the photoelectric effect, however only light with some minimum frequency and threshold energy can cause an electron to be ejected.

18. Compare the ground state and the excited state of an electron.

The ground state is the lowest energy level of an electron. The excited state is an energy state higher than the ground state.

19. Arrange the following in order of decreasing wavelength.

a. infrared radiation from a lamp
b. dental x-rays
c. signal from a shortwave radio station

Answer: c, a, b

Chapter 13 Review

Concept Practice

20. Which subatomic particles did Thomson include in the plum-pudding model of the atom? 13.1

Electrons, which he had identified, and positively-charged, unnamed particles.

23. What is the significance of the boundary of an electron cloud?

The boundary defines where we would expect to find a given electron 90% of the time.

24. What is an atomic orbital?

The region beyond the atomic nucleus where there is a high probability of finding a given electron.

25. Sketch *1s*, *2s*, and *2p* orbitals using the same scale for each. 13.1

1s	*2s*	$2p_x$	$2p_y$	$2p_z$

27. What are the three rules that govern the filling of atomic orbitals? 13.2

Aufbau principle: electrons occupy the lowest possible energy levels.

Pauli exclusion principle: an orbital can hold at most two electrons.

Hund's rule: before pairing of electrons occurs within a given orbital, one electron occupies each of a set of orbitals with equal energies.

31. What is the maximum number of electrons that can go into each of the following sublevels? 13.2

a. 2s _____ 2 b. 3p _____ 6 c. 4s _____ 2 d. 3d _____ 10

e. 4p _____ 6 f. 5s _____ 2 g. 4f _____ 14 h. 5p _____ 6

32. How many electrons are in the second energy level of an atom of each element? 13.2

a. chlorine – 8

b. phosphorus – 8

c. potassium – 8

34. List the color of the visible spectrum in order of increasing wavelength. 13.3

Violet, indigo, blue, green, yellow, orange, red

35. What is meant by the frequency of a wave? What are the units of frequency? Describe the relationship between frequency and wavelength. 13.3

Frequency refers to the number of wave cycles that pass a given point per unit time. Frequency *units* are cycles, reciprocal seconds (s^{-1}), or hertz. Frequency and wavelength are inversely related.

36. Use a diagram to illustrate each term. 13.3

a. wavelength
b. amplitude
c. wave cycle

37. Explain the difference between the laws of classical physics and the quantum concept when describing the energy lost or gained by an object. 13.3

Classical physics viewed energy changes as continuous, occurring in any quantity. In the quantum concept, energy changes occur in discrete units called quanta.

38. What is the energy of a photon of green light with a frequency of 5.80 x 10^{14} s^{-1}?

Use E = hv

$E = (6.6262\ x\ 10^{-34} J \cdot s)(5.80\ x\ 10^{14} s^{-1}) = 3.84\ x\ 10^{-19} J$

41. Explain the difference between a photon and a quantum. 13.3

A quantum is a discrete amount of energy – almost like an energy packet. Photons are more specifically light quantas.

Concept Mastery

45. Provide the symbol for the atom that corresponds to each electron configuration.

a. $1s^2 2s^2 2p^6 3s^2 3p^6$ Ar

b. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^7 5s^1$ Ru

c. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^7 5s^2 5p^6 5d^1 6s^2$ Gd

47. How many paired electrons are there in an atom of each element?

a. helium 2 b. boron 4 c. sodium 10 d. oxygen 6

48. An atom of an element has two electrons in the first energy level and five electrons in the second level. Write the electron configuration for this atom and name the element. How many unpaired electrons does an atom of this element have?

$1s^2 2s^2 2p^3$; nitrogen; three unpaired electrons residing in p orbitals.

52. Provide the symbol and name of the elements that correspond to these configurations.

a. $1s^2 2s^2 2p^6 3s^1$	Sodium	Na
b. $1s^2 2s^2 2p^3$	Nitrogen	N
c. $1s^2 2s^2 2p^6 3s^2 3p^2$	Silicon	Si
d. $1s^2 2s^2 2p^4$	Oxygen	O
e. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$	Potassium	K
f. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	Titanium	Ti