Chapter 7

ATOMIC STRUCTURE

USEFUL CONSTANTS:

\[ 1 \text{ nm} = 1.0 \times 10^{-9} \text{ m} \]

velocity of light \( = 3.0 \times 10^{8} \text{ m/s} \)

\[ h = \text{Planck's constant} = 6.6261 \times 10^{-34} \text{ J \cdot s} \]

7-1. If the frequency is observed to be \( 1.00 \times 10^{12} \text{ Hz} \) for a microwave signal, what is the wavelength of this radiation in centimeters? (1 Hz = 1 cycle per second)

(a) \( 3.00 \times 10^{-4} \text{ cm} \)  
(b) \( 3.00 \times 10^{-2} \text{ cm} \)  
(c) \( 3.34 \text{ cm} \)  
(d) \( 3340 \text{ cm} \)

7-2. If red light has a frequency of \( 4.28 \times 10^{14} \text{ Hz} \), what is the wavelength of this light?

(a) \( 0.650 \text{ nm} \)  
(b) \( 2.10 \text{ nm} \)  
(c) \( 65.0 \text{ nm} \)  
(d) \( 700 \text{ nm} \)

7-3. A local radio station has a frequency of 98.6 megahertz (MHz). What is the wavelength of this station in centimeters? (1 MHz = \( 1.00 \times 10^{6} \text{ cycles per second} \))

(a) \( 304 \text{ cm} \)  
(b) \( 37.1 \text{ cm} \)  
(c) \( 0.329 \text{ cm} \)  
(d) \( 0.00289 \text{ cm} \)

7-4. Which of the following produces radiation having the highest frequency?

(a) microwave oven  
(b) AM radio  
(c) radar  
(d) FM radio

7-5. Which of the following types of radiation has the longest wavelength?

(a) gamma rays  
(b) visible  
(c) ultraviolet  
(d) radar

7-6. Which of the following has the longest wavelength?

(a) blue light  
(b) red light  
(c) yellow light  
(d) green light

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7-7. Which of the following types of radiation has the highest energy?
(a) gamma rays         (b) visible
(c) ultraviolet        (d) radar

7-8. What is the frequency of green light having a wavelength of 521 nanometers?
(a) $5.21 \times 10^7$ Hz  (b) $5.75 \times 10^7$ Hz
(c) $5.75 \times 10^{11}$ Hz (d) $5.75 \times 10^{14}$ Hz

7-9. What is the frequency in megahertz of a radio station that broadcasts at a wavelength of 325 centimeters? (1 MHz = $1.00 \times 10^6$ cycles per second)
(a) 22.1 MHz     (b) 67.1 MHz
(c) 92.2 MHz       (d) 108 MHz

7-10. What is the frequency in megahertz of a radio set that is broadcasting at 99.9 meters?
(a) 3.00 MHz     (b) 15.7 MHz
(c) 33.3 MHz       (d) 299 MHz

7-11. In the Rutherford scattering experiment, Rutherford bombarded a thin piece of gold foil with a beam of
(a) electrons      (b) neutrons
(c) protons          (d) alpha rays

7-12. In the Rutherford scattering experiment, what did Rutherford observe to happen to the beam of particles that bombarded the thin piece of gold foil?
(a) None of the particles were deflected.
(b) Only a few particles were deflected, but the deflection was large.
(c) Most of the particles were slightly deflected.
(d) Most of the particles were greatly deflected.

7-13. Based on these observations from the scattering experiment, what did Rutherford conclude?
(a) The positive part of the atoms is moving very rapidly.
(b) The positive charge is distributed throughout the atom.
(c) The positive part of the atom is relatively small and heavy.
(d) The negative part of the atom is relatively small and heavy.
7-14. According to the experiments concerned with the photoelectric effect, what was the result of increasing the intensity of the light striking the metal surface?
(a) The number of electrons emitted was increased.
(b) The energy of the electrons emitted was increased.
(c) Both the number and energy of the electrons was increased.
(d) There was no change in the number or energy of the electrons.

7-15. According to the experiments concerned with the photoelectric effect, what was the relationship between the frequency of the light striking the metal surface and the number of electrons emitted?
(a) The lower the frequency the greater the number of electrons emitted.
(b) The higher the frequency the greater the number of electrons emitted.
(c) Below a certain frequency, no electrons were emitted.
(d) There was no relationship between the frequency and the number of electrons.

7-16. Planck suggested that all energy gained or lost by an atom must be some integral multiple of a minimum amount of energy called a(n) ______.
(a) electron    (b) nucleus
(c) spectral line (d) quantum

7-17. If the frequency of ultraviolet light is $5.0 \times 10^{13}$ Hz, what is the energy of one quantum of this radiation?
(a) $8.0 \times 10^{46}$ J   (b) $5.7 \times 10^{-6}$ J
(c) $3.5 \times 10^{-20}$ J   (d) $2.9 \times 10^{-27}$ J

7-18. If the frequency of infrared light is $2.15 \times 10^{14}$ Hz, what is the energy of one quantum of this radiation?
(a) $5.31 \times 10^{11}$ J   (b) $7.87 \times 10^{-7}$ J
(c) $1.43 \times 10^{-19}$ J   (d) $9.24 \times 10^{-40}$ J

7-19. If the wavelength of infrared light is $1.5 \times 10^{-3}$ cm, what is the energy of one quantum of this radiation?
(a) $9.9 \times 10^{-37}$ J   (b) $9.4 \times 10^{-27}$ J

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7-20. If the wavelength of ultraviolet light is 125 nanometers, what is the energy of one quantum of this radiation?

(a) $6.19 \times 10^{-14}$ J  
(b) $1.59 \times 10^{-18}$ J  
(c) $3.60 \times 10^{-23}$ J  
(d) $1.3 \times 10^{-20}$ J

7-21. If the wavelength of radio waves is 95.6 meters, what is the energy of one quantum of this radiation?

(a) $3.99 \times 10^{-11}$ J  
(b) $5.03 \times 10^{-15}$ J  
(c) $2.17 \times 10^{-25}$ J  
(d) $2.08 \times 10^{-27}$ J

7-22. For an electron (mass = $9.109 \times 10^{-31}$ kg) moving with a velocity of $3.00 \times 10^7$ m/s, what is the de Broglie wavelength in meters?

(a) $1.37 \times 10^9$ m  
(b) $6.28 \times 10^{-8}$ m  
(c) $2.43 \times 10^{-11}$ m  
(d) $1.37 \times 10^{-10}$ m

7-23. For a neutron (mass = $1.675 \times 10^{-27}$ kg) moving with a velocity of 4.20 m/s, what is the de Broglie wavelength in nanometers?

(a) 0.245 nm  
(b) 0.824 nm  
(c) 1.34 nm  
(d) 94.2 nm

7-24. What is the wavelength in nanometers of a bullet (mass = 1.50 kg) moving with a velocity $8.00 \times 10^7$ cm/s?

(a) $5.52 \times 10^{-28}$ nm  
(b) $5.52 \times 10^{-30}$ nm  
(c) $5.52 \times 10^{-31}$ nm  
(d) $5.52 \times 10^{-33}$ nm

7-25. Which of the following electronic transitions in a hydrogen atom would have the longest wavelength?

(a) $n = 4$ to $n = 1$  
(b) $n = 4$ to $n = 2$  
(c) $n = 2$ to $n = 1$  
(d) $n = 4$ to $n = 3$
7-26. Which of the following electronic transitions in a hydrogen atom would have the highest energy?

(a) \( n = 4 \) to \( n = 1 \)  
(b) \( n = 4 \) to \( n = 2 \)  
(c) \( n = 2 \) to \( n = 1 \)  
(d) \( n = 4 \) to \( n = 3 \)

7-27. Calculate the energy change associated with the third line of the Balmer Series for hydrogen gas, that is, the line that results when an electron moves from \( n = 5 \) to \( n = 2 \).

(\( \text{Rhc} = -1313 \text{ kJ/mole} \))

(a) -275.7 kJ/mole  
(b) -393.9 kJ/mole  
(c) -486.0 kJ/mole  
(d) -699.2 kJ/mole

7-28. Calculate the energy change associated with the fifth line of the Lyman Series for hydrogen gas, that is, the transition resulting when an electron moves from \( n = 6 \) to \( n = 1 \).

(\( \text{Rhc} = -1313 \text{ kJ/mole} \))

(a) -1094 kJ/mole  
(b) -1276 kJ/mole  
(c) -1782 kJ/mole  
(d) -2931 kJ/mole

7-29. Excited H atoms emit visible light when electrons fall from higher levels to \( n = 2 \) (this is called the Balmer series of lines). If green light comes from the transition from \( n = 4 \) to \( n = 2 \), is the light from the \( n = 3 \) to \( n = 2 \) transition expected to be red or blue?

(a) red  
(b) blue

7-30. Excited H atoms emit light of another region of the spectrum when electrons fall from higher levels to the \( n = 3 \) level. This is called the Ritz-Paschen series. The transition from \( n = \) ____ to \( n = 3 \) accounts for the least energetic line of this series.

(a) 2  
(b) 3  
(c) 4  
(d) 5

7-31. Excited H atoms emit visible light when electrons fall from higher levels to \( n = 2 \). Is the light coming from the transition \( n = 2 \) to \( n = 1 \) expected to be in the infrared region or the ultraviolet region of the spectrum?

(a) infrared  
(b) ultraviolet

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7-32. Radiation in the ultraviolet region of the electromagnetic spectrum is quite energetic. It is this radiation that causes dyes to fade and your skin to burn. If you are bombarded with one mole of photons with a wavelength of 300 nm, what amount of energy are you being subjected to?

(a) $6.63 \times 10^{-19}$ J (b) $4.00 \times 10^{-10}$ kJ
(c) 40,000 kJ (d) 400 kJ

7-33. Consider only the following quantum levels for the H atom.

\[ \begin{array}{c}
\text{ } \\
\text{n} = 5 \\
\text{n} = 4 \\
\text{n} = 3 \\
\text{n} = 2 \\
\text{n} = 1
\end{array} \]

The emission spectrum of an excited H atom will consist of transitions between these levels.

(i) How many emission lines are possible, considering only the five quantum levels above? _______________

(ii) Photons of the highest frequency will be emitted in a transition from the level with \( n = \) _____ to the level with \( n = \) ______.

(iii) The emission line having the longest wavelength corresponds to a transition from the level with \( n = \) ______ to the level with \( n = \) ______.

7-34. An advertising sign gives off red light and green light.

(i) Which light has the higher energy photons? _______________

(ii) One of the colors has a wavelength of 680 nm and the other has a wavelength of 500 nm. Identify which color has which wavelength.

500 nm = ______________ 680 nm = _______________

(iii) Which light has the higher frequency? _______________

7-35. When \( n = 3 \), which of the following is a possible value for \( \ell \)?

(a) -1 (b) 0
(c) 3 (d) 6

7-36. When \( \ell = 2 \), which of the following is a possible value for \( m_\ell \)?

(a) -3 (b) 1
(c) 3 (d) 4
7-37. When \( \ell = 2 \), what is the maximum number of orbitals of this type possible in a given electron shell (i.e. for a particular \( n \) value)?

(a) 3  
(b) 5
(c) 7  
(d) 9

7-38. When \( \ell = 2 \), what set of orbitals is designated?

(a) p  
(b) d
(c) f  
(d) g

7-39. When \( \ell = 4 \), what is the maximum number of orbitals of this type possible in a given electron shell (i.e. for a particular \( n \) value)?

(a) 3  
(b) 5
(c) 7  
(d) 9

7-40. When \( \ell = 4 \), what set of orbitals is designated?

(a) p  
(b) d
(c) f  
(d) g

7-41. What name is given to a region of an electron probability density graph where the probability of finding the electron is zero?

(a) node  
(b) wave function
(c) orbital  
(d) lobe

7-42. The lowest-energy stationary state of an atom is called its __________.

(a) wave function  
(b) node
(c) ground state  
(d) orbital

7-43. Each quantum mechanical wave function does not have a readily interpretable physical meaning, but the square of the wave function gives the __________ of finding the electron at a certain point.

(a) Bohr orbital  
(b) probability
(c) energy  
(d) velocity

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7-44. According to Heisenberg's uncertainty principle, if one attempts simultaneously to measure the position and momentum of an electron, the more exactly the position is measured, the greater will be the ________ in the momentum measurement.
(a) value                (b) probability
(c) uncertainty         (d) energy

7-45. Which of the following is associated with the value of the $\ell$ quantum number?
(a) orbital size            (b) orbital orientation
(c) orbital shape        (d) orbital uncertainty

7-46. Which of the following is associated with the value of the $m_\ell$ quantum number?
(a) orbital size            (b) orbital orientation
(c) orbital shape        (d) orbital uncertainty

7-47. Which of the following is NOT a valid set of quantum numbers?
(a) $n = 4$, $\ell = 0$, and $m_\ell = -1$
(b) $n = 6$, $\ell = 5$, and $m_\ell = 0$
(c) $n = 2$, $\ell = 1$, and $m_\ell = +1$
(d) $n = 3$, $\ell = 2$, and $m_\ell = -2$

7-48. Which of the following is NOT a valid set of quantum numbers?
(a) $n = 4$, $\ell = 1$, and $m_\ell = -1$
(b) $n = 6$, $\ell = 5$, and $m_\ell = 0$
(c) $n = 2$, $\ell = 2$, and $m_\ell = +1$
(d) $n = 3$, $\ell = 2$, and $m_\ell = -2$

7-49. If $m_\ell = +1$ for a certain orbital, this orbital CANNOT be which of the following?
(a) s orbital    (b) p orbital
(c) d orbital      (d) f orbital

7-50. For a certain orbital, $n = 4$, $\ell = 1$, and $m_\ell = -1$. What type of orbital is this?
(a) 3p    (b) 4s
(c) 4p    (d) 4d

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7-51. For a certain orbital, $n = 3$, $\ell = 1$, and $m_{\ell} = -1$. What type of orbital is this?

(a) 3p  (b) 4s  
(c) 4p  (d) 4d

7-52. If an electron subshell has 9 orbitals, what is the $\ell$ value for this subshell?

(a) two  (b) three  
(c) four  (d) five

7-53. If an electron subshell has 7 orbitals, what is the $\ell$ value for this subshell?

(a) two  (b) three  
(c) four  (d) five

7-54. Atomic structure and quantum numbers

(i) When $n = 4$, the possible values of $\ell$ are _______.

(ii) What type of orbital corresponds to $\ell = 2?$ ______

(iii) The quantum number $n$ describes the ______ of an atomic orbital and the quantum number $\ell$ describes its _________.

(iv) For a 4$d$ orbital, the value of $n$ is _____, the value of $\ell$ is _____, and one possible value of $m_{\ell}$ is _____.

(v) For a 5$f$ orbital, the value of $n$ is _____, the value of $\ell$ is _____, and a possible value of $m_{\ell}$ is _____.

(vi) Each drawing below represents a type of atomic orbital. Give the letter designation for the orbital and its value of $\ell$.

(a)  
(b)  
(c)  

letter = _______ _______ _______

$\ell$ value = _______ _______ _______
(vii) How many nodal planes does the first orbital above (= a) have? _________
(viii) An atomic orbital with 1 nodal plane is ___________.

ANSWERS — CHAPTER 7

1. b 11. d 21. d
2. d 12. b 22. c
3. a 13. c 23. d
4. a 14. a 24. c
5. d 15. c 25. d
6. b 16. d 26. a
7. a 17. c 27. a
8. d 18. c 28. b
9. c 19. d 29. a
10. a 20. b 30. c
31. b 41. a 51. a
32. d 42. c 52. c
33. i = 10; ii = 5,1; iii = 5,4 43. b 53. b
34. i = green; ii: 500 = green and 680 = red; iii = green 44. c 54. i = 0, 1, 2, 3
35. b 45. c 55. iii = size,shape
36. b 46. b 56. iv = 4, 2, -1
37. b 47. a 57. v = 5, 3, +3
38. b 48. c 58. vi(a) = d, 2
39. d 49. a 59. vi(b) = s, 0
40. d 50. c 60. vi(c) = p, 1
   vii = 2
   viii = p

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