Chapter 7 Quantum Theory and the Electronic Structure of Atoms

Student: ____

1. What is the wavelength of radiation that has a frequency of 6.912×10^{14} s^{-1}?

   A. 1.447×10^{-15} nm
   B. 4.337×10^{2} nm
   C. 2.304×10^{6} nm
   D. 2.074×10^{23} nm
   E. 4.337×10^{-7} nm

2. What is the wavelength of radiation that has a frequency of 2.10×10^{14} s^{-1}?

   A. 6.30×10^{22} m
   B. 7.00×10^{2} nm
   C. 7.00×10^{5} m
   D. 1.43×10^{-6} m
   E. 3.00×10^{8} m

3. Calculate the frequency of visible light having a wavelength of 486 nm.

   A. 2.06×10^{14} /s
   B. 2.06×10^{6} /s
   C. 6.17×10^{14} /s
   D. 1.20×10^{-15} /s
   E. 4.86×10^{-7} /s

4. Calculate the frequency of visible light having a wavelength of 686 nm.

   A. 4.37×10^{14} /s
   B. 4.37×10^{5} /s
   C. 6.17×10^{14} /s
   D. 2.29×10^{-15} /s
   E. 2.29×10^{-6} /s

5. What is the energy in joules of one photon of microwave radiation with a wavelength 0.122 m?

A. 2.70×10^{-43} J
B. 5.43×10^{-33} J
C. 1.63×10^{-24} J
D. 4.07×10^{-10} J
E. 2.46×10^{9} J

6. What is the energy in joules of a mole of photons associated with visible light of wavelength 486 nm?

A. 6.46×10^{-16} J
B. 6.46×10^{-25} J
C. 2.46×10^{-4} J
D. 12.4 kJ
E. 246 kJ

7. What is the energy in joules of a mole of photons associated with red light of wavelength 7.00×10^{2} nm?

A. 256 kJ
B. 1.71×10^{5} J
C. 4.72×10^{-43} J
D. 12.4 kJ
E. 2.12×10^{42} J

8. What is the binding energy (in J/mol or kJ/mol) of an electron in a metal whose threshold frequency for photoelectrons is 2.50×10^{14} /s?

A. 99.7 kJ/mol
B. 1.66×10^{-19} J/mol
C. 2.75×10^{-43} J/mol
D. 7.22×10^{17} kJ/mol
E. 1.20×10^{-6} J/mol

9. Complete this sentence: Atoms emit visible and ultraviolet light

A. as electrons jump from lower energy levels to higher levels.
B. as the atoms condense from a gas to a liquid.
C. as electrons jump from higher energy levels to lower levels.
D. as they are heated and the solid melts to form a liquid.
E. as the electrons move about the atom within an orbit.

10. Calculate the energy, in joules, required to excite a hydrogen atom by causing an electronic transition from the n = 1 to the n = 4 principal energy level. Recall that the energy levels of the H atom are given by

$E_n = -2.18 \times 10^{-18}\ J(1/n^2)$

A. 2.07×10^{-29} J
B. 2.19×10^{5} J
C. 2.04×10^{-18} J
D. 3.27×10^{-17} J
E. 2.25×10^{-18} J

11. Calculate the wavelength, in nanometers, of the light emitted by a hydrogen atom when its electron falls from the n = 7 to the n = 4 principal energy level. Recall that the energy levels of the H atom are given by

$E_n = -2.18 \times 10^{-18}\ J(1/n^2)$

A. 4.45×10^{-20} nm
B. 2.16×10^{-6} nm
C. 9.18×10^{-20} nm
D. 1.38×10^{14} nm
E. 2.16×10^{3} nm

12. Calculate the frequency of the light emitted by a hydrogen atom during a transition of its electron from the n = 6 to the n = 3 principal energy level. Recall that for hydrogen

$E_n = -2.18 \times 10^{-18}\ J(1/n^2)$.

A. 1.64×10^{15} /s
B. 9.13×10^{13} /s
C. 3.65×10^{14} /s
D. 1.82×10^{-19} /s
E. 2.74×10^{14}/s

13. Calculate the frequency of the light emitted by a hydrogen atom during a transition of its electron from the n = 4 to the n = 1 principal energy level. Recall that for hydrogen

$E_n = -2.18 \times 10^{-18}\ J(1/n^2)$

A. 3.08×10^{15} /s
B. 1.03×10^{8} /s
C. 2.06×10^{14} /s
D. 1.35×10^{-51} /s
E. 8.22×10^{14} /s

14. Calculate the wavelength of the light emitted by a hydrogen atom during a transition of its electron from the n = 4 to the n = 1 principal energy level. Recall that for hydrogen

$E_n = -2.18 \times 10^{-18}\ J(1/n^2)$

A. 97.2 nm
B. 82.6 nm
C. 365 nm
D. 0.612 nm
E. 6.8×10^{-18} nm

15. The second line of the Balmer series occurs at a wavelength of 486.1 nm. What is the energy difference between the initial and final levels of the hydrogen atom in this emission process?

A. 2.44×10^{18} J
B. 4.09×10^{-19} J
C. 4.09×10^{-22} J
D. 4.09×10^{-28} J
E. 1.07×10^{-48} J

16. In an electron microscope, electrons are accelerated to great velocities. Calculate the wavelength of an electron traveling with a velocity of 7.0×10^3 kilometers per second. The mass of an electron is 9.1×10^{-28} g.

A. 1.0×10^{-13} m
B. 1.0×10^{-7} m
C. 1.0 m
D. 1.0×10^{-10} m

17. Calculate the wavelength associated with a $^{20}Ne^+$ ion moving at a velocity of 2.0 $\times 10^5$ m/s. The atomic mass of Ne-20 is 19.992 amu.

A. 1.0×10^{-13} m
B. 1.0×10^{-16} m
C. 1.0×10^{-18} m
D. 9.7×10^{12} m
E. 2.0×10^{-13} cm

18. Calculate the wavelength of a neutron that has a velocity of 200. cm/s. (The mass of a neutron = 1.675×10^{-27} kg.)

A. 1.98×10^{-9} m
B. 216 nm
C. 1.8×10^{50} m
D. 198 nm
E. 5.05 mm

19. A common way of initiating certain chemical reactions with light involves the generation of free halogen atoms in solution. If ΔH for the reaction $Cl_2(g) \rightarrow 2Cl(g)$ is 242.8 kJ/mol, what is the longest wavelength of light that will produce free chlorine atoms in solution?

A. 246.3 nm
B. 465.2 nm
C. 349.3 nm
D. 698.6 nm
E. 492.6 nm

20. The longest wavelength of light that causes electrons to be ejected from the surface of a copper plate is 243 nm. What is the maximum velocity of the electrons ejected when light of wavelength 200. nm shines on a copper plate?

A. 1.48×10^6 m/s
B. 6.22×10^5 m/s
C. 4.67×10^4 m/s
D. 1.97×10^4 m/s
E. 1.34×10^6 m/s

21. When photons with a wavelength of 310. nm strike a magnesium plate, the maximum velocity of the ejected electrons is 3.45×10^5 m/s. Calculate the binding energy of electrons to the magnesium surface.

A. 386 kJ/mol
B. 419 kJ/mol
C. 32.7 kJ/mol
D. 321 kJ/mol
E. 353 kJ/mol

22. Electrons can be used to probe the arrangement of atoms on a solid surface if the wavelength of the electrons is comparable with the spacing between the atoms. Which of the following electron velocities would be appropriate for use in this application if the atoms are separated by 0.320 nm?

A. 2.27×10^6 m/s
B. 1.24×10^3 m/s
C. 3.00×10^8 m/s
D. 4.41×10^6 m/s
E. 8.06×10^3 m/s

23. A single pulse of a laser yields an average of 5.00×10^{18} photons with $\lambda = 633$ nm. If melting ice to water at 0°C requires 6.01 kJ/mol, what is the fewest number of laser pulses need to melt 10.0 g of ice?

A. 3830
B. 3340
C. 38300
D. 2120
E. 212

24. Which one of the following sets of quantum numbers is not possible?

	n	l	m_l	m_s
Row 1	4	3	–2	+1/2
Row 2	3	0	1	–1/2
Row 3	3	0	0	+1/2
Row 4	2	1	1	–1/2
Row 5	2	0	0	+1/2

A. Row 1
B. Row 2
C. Row 3
D. Row 4
E. Row 5

25. Which one of the following sets of quantum numbers is not possible?

	n	l	m_l	m_s
Row 1	4	3	–2	+1/2
Row 2	3	2	–3	–1/2
Row 3	3	0	0	+1/2
Row 4	4	1	1	–1/2
Row 5	2	0	0	+1/2

A. Row 1
B. Row 2
C. Row 3
D. Row 4
E. Row 5

26. What is the maximum number of electrons in a atom that can have the following set of quantum numbers?

$n = 4$ $\quad l = 3$ $\quad m_l = -2$ $\quad m_s = +1/2$

A. 0
B. 1
C. 2
D. 6
E. 10

27. A possible set of quantum numbers for the last electron added to complete an atom of gallium Ga in its ground state is

	n	l	m_l	m_s
Row 1	4	0	0	−1/2
Row 2	3	1	0	−1/2
Row 3	4	1	0	+1/2
Row 4	3	1	1	+1/2
Row 5	4	2	1	+1/2

A. Row 1.
B. Row 2.
C. Row 3.
D. Row 4.
E. Row 5.

28. A possible set of quantum numbers for the last electron added to complete an atom of germanium in its ground state is

	n	l	m_l	m_s
Row 1	4	0	0	+1/2
Row 2	3	0	+1	−1/2
Row 3	4	1	−1	+1/2
Row 4	3	1	+1	−1/2
Row 5	4	2	+2	−1/2

A. Row 1.
B. Row 2.
C. Row 3.
D. Row 4.
E. Row 5.

29. Electrons in an orbital with $l = 3$ are in a

A. *d* orbital.
B. *f* orbital.
C. *g* orbital.
D. *p* orbital.
E. *s* orbital.

30. The number of orbitals in a *d* subshell is

A. 1.
B. 2.
C. 3.
D. 5.
E. 7.

31. The maximum number of electrons that can occupy an energy level described by the principal quantum number, *n*, is

A. n.
B. $n + 1$.
C. $2n$.
D. $2n^2$.
E. n^2.

32. How many orbitals are allowed in a subshell if the angular momentum quantum number for electrons in that subshell is 3?

A. 1
B. 3
C. 5
D. 7
E. 9

33. "No two electrons in an atom can have the same four quantum numbers" is a statement of

A. the Pauli exclusion principle.
B. Bohr's equation.
C. Hund's rule.
D. de Broglie's relation.
E. Dalton's atomic theory.

34. The orbital diagram for a ground-state nitrogen atom is

	1s	2s	2p		
Row 1	↑↓	↑↓	↑	↑	↑
Row 2	↑↓	↑↓	↑↓	↑	__
Row 3	↑↓	↑	↑	↑	↑
Row 4	↑↓	↑↓	↑↓	↑	↑

A. Row 1.
B. Row 2.
C. Row 3.
D. Row 4.

35. The orbital diagram for a ground-state oxygen atom is

	1s	2s	2p		
Row 1	↑↓	↑↓	↑	↑	↑
Row 2	↑↓	↑↓	↑↓	↑↓	___
Row 3	↑↓	↑↓	↑↓	↑↓	___
Row 4	↑↓	↑↓	↑↓	↑	↑
Row 5	↑↓	↑↓	↑↓	↑↓	↑

A. Row 1.
B. Row 2.
C. Row 3.
D. Row 4.
E. Row 5.

36. The orbital diagram for a ground state carbon atom is

	1s	2s	2p		
Row 1	↑↓	↑↓	↑	___	___
Row 2	↑↓	↑	↑	↑	↑
Row 3	↑↓	↑↓	↑	↑	↑
Row 4	↑↓	↑↓	↑	↑	___

A. Row 1.
B. Row 2.
C. Row 3.
D. Row 4.

37. Which ground-state atom has an electron configuration described by the following *orbital diagram*?

	4s	3d					4p		
[Ar]	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑	↑

A. phosphorus
B. germanium
C. selenium
D. tellurium
E. none of these

38. Which ground-state atom has an electron configuration described by the following *orbital diagram*?

[Ne] ↑↓ (3s) ↑ ↑ ↑ (3p)

A. phosphorus
B. nitrogen
C. arsenic
D. vanadium
E. none of these

39. How many unpaired electrons does a ground-state atom of sulfur have?

A. 0
B. 1
C. 2
D. 3
E. 4

40. Which element has the following ground-state electron configuration?

$1s^2 2s^2 2p^6 3s^2$

A. Na
B. Mg
C. Al
D. Si
E. Ne

41. Which element has the following ground-state electron configuration?

$[Kr]5s^2 4d^{10} 5p^3$

A. Sn
B. Sb
C. Pb
D. Bi
E. Te

42. Which element has the following ground-state electron configuration?

$[Kr]5s^2 4d^{10} 5p^2$

A. Sn
B. Sb
C. Pb
D. Ge
E. Te

43. The electron configuration of a ground-state Co atom is

A. $[Ar]4s^2 3d^7$.
B. $1s^2 2s^2 2p^6 3s^2 3d^9$.
C. $[Ne]3s^2 3d^7$.
D. $[Ar]4s^1 3d^5$.
E. $[Ar]4s^2 4d^7$.

44. The electron configuration of a ground-state vanadium atom is

A. $[Ar]4s^2 4d^3$.
B. $[Ar]4s^2 4p^3$.
C. $[Ar]4s^2 3d^3$.
D. $[Ar]3d^5$.

45. The electron configuration of a ground-state copper atom is

A. $[Ar]4s^2 4d^4$.
B. $[Ar]4s^2 4p^6 3d^3$.
C. $[Ar]4s^2 3d^9$.
D. $[Ar]3d^9$.
E. $[Ar]4s^1 3d^{10}$.

46. The ground-state electron configuration for an atom of indium is

A. $[Kr]5s^2 4p^6 4d^5$.
B. $[Ar]4s^2 3d^{10} 4p^1$.
C. $[Ar]4s^2 4p^6 3d^5$.
D. $[Kr]5s^2 5p^6 4d^5$.
E. $[Kr]5s^2 4d^{10} 5p^1$.

47. The ground-state electron configuration of a calcium atom is

A. $[Ne]3s^2$.
B. $[Ne]3s^2 3p^6$.
C. $[Ar]4s^1 3d^1$.
D. $[Ar]4s^2$.
E. $[Ar]3d^2$.

48. How many electrons are there in the 2nd principal energy level (n = 2) of a phosphorus atom?

A. 3
B. 5
C. 6
D. 8
E. 10

49. How many electrons are there in the 3rd principal energy level (n = 3) of a phosphorus atom?

A. 3
B. 5.
C. 6
D. 8
E. 10

50. A ground-state atom of manganese has ___ unpaired electrons and is _____.

A. 0, diamagnetic
B. 2, diamagnetic
C. 3, paramagnetic
D. 5, paramagnetic
E. 7, paramagnetic

51. A ground-state atom of vanadium has ___ unpaired electrons and is _____.

A. 0, diamagnetic
B. 2, diamagnetic
C. 3, paramagnetic
D. 5, paramagnetic
E. 4, diamagnetic

52. A ground-state atom of iron has ___ unpaired electrons and is _____.

A. 0, diamagnetic
B. 6, diamagnetic
C. 3, paramagnetic
D. 5, paramagnetic
E. 4, paramagnetic

53. Transition metal elements have atoms or ions with partially filled

A. *s* subshells.
B. *p* subshells.
C. *d* subshells.
D. *f* subshells.
E. *g* subshells.

54. Lanthanide (or *rare earth* elements) have atoms or ions with partially filled

A. *s* subshells.
B. *p* subshells.
C. *d* subshells.
D. *f* subshells.
E. *g* subshells.

55. Which choice lists two elements with ground-state electron configurations that are well-known exceptions to the Aufbau principle?

A. Cu and C
B. Cr and Cu
C. Cs and Cl
D. Rb and Co
E. Fe and Co

56. A ground-state chromium atom has how many unpaired electrons?

A. 1
B. 2
C. 4
D. 5
E. 6

57. Which of these choices is the electron configuration of an *excited state* of an oxygen atom?

A. $1s^2 2s^2 2p^4$
B. $1s^2 2s^2 2p^5$
C. $1s^2 2s^2 2p^3 3s^1$
D. $1s^2 2s^2 2p^6$
E. $1s^2 2s^2 2p^3$

58. Which of these choices is the electron configuration of an *excited state* of an iron atom?

A. $[Ar]4s^2 3d^7$
B. $[Ar]4s^2 3d^6$
C. $[Ar]4s^2 3d^8$
D. $[Ar]4s^1 3d^7$
E. $[Ar]4s^1 3d^5$

59. Which of these choices is the electron configuration of an *excited state* of a copper atom?

A. $[Ar]4s^2 3d^9$
B. $[Ar]4s^1 3d^{10}$
C. $[Ar]4s^1 3d^8$
D. $[Ar]4s^2 3d^8$
E. $[Ar]4s^0 3d^{10}$

60. The ground-state electron configuration of Cr, Mo, and Ag are exceptions to the Aufbau principle. Which of the following is the electron configuration for Mo?

A. $[Kr]5s^1 4d^5$
B. $[Kr]5s^2 4d^4$
C. $[Xe]6s^2 5d^4$
D. $[Ar]4s^2 4d^4$
E. $[Kr]5s^2 4d^6$

61. How many electrons in a ground-state tellurium atom are in orbitals labeled by $l = 1$?

A. 4
B. 10
C. 12
D. 16
E. 22

62. How many electrons in a ground-state cadmium atom are in orbitals labeled by $m_l = -1$?

A. 2
B. 10
C. 12
D. 18
E. 36

63. Which of these ground-state atoms is diamagnetic?

A. Ca
B. As
C. Cu
D. Fe
E. none of these

64. Which of these atoms is paramagnetic both in its ground state and in *all* of its excited states?

A. C
B. N
C. O
D. Ti
E. Cr

65. Which of these atoms is diamagnetic both in its ground state and in *all* of its excited states?

A. Mg
B. Ne
C. Cu
D. Zn
E. none of these

66. The electron in a hydrogen atom falls from an excited energy level to the ground state in two steps, causing the emission of photons with wavelengths of 2624 and 97.2 nm. What is the quantum number of the initial excited energy level from which the electron falls?

A. 2
B. 3
C. 4
D. 6
E. 8

67. The electron in a hydrogen atom falls from an excited energy level to the ground state in two steps, causing the emission of photons with wavelengths of 1870 and 102.5 nm. What is the quantum number of the initial excited energy level from which the electron falls?

A. 2
B. 3
C. 4
D. 6
E. 8

68. When the electron in a hydrogen atom falls from the $n = 3$ excited energy level to the ground state energy level, a photon with wavelength λ is emitted. An electron having this same wavelength would have a velocity of

A. 7.10×10^3 m/s.
B. 2.93×10^6 m/s.
C. 2.93×10^3 m/s.
D. 7.10 m/s.
E. 3.00×10^8 m/s.

69. When the electron in a hydrogen atom falls from its first excited energy level to the ground state energy level, a photon with wavelength λ is emitted. A proton having this same wavelength would have a velocity of

A. 3.87 m/s.
B. 5990 m/s.
C. 1.21×10^{-7} m/s.
D. 3.26 m/s.
E. 5.99 m/s.

70. Breaking the oxygen-oxygen bond in hydrogen peroxide requires 210 kJ/mol. What is the longest wavelength of light that can cause this bond to be broken?

A. 5.7×10^{-4} m
B. 9.5×10^{-31} m
C. 2.8×10^{-7} m
D. 9.5×10^{-28} m
E. 5.7×10^{-7} m

71. A photovoltaic cell converts light into electrical energy. Suppose a certain photovoltaic cell is only 63.5% efficient, in other words, that 63.5% of the light energy is ultimately recovered. If the energy output of this cell is used to heat water, how many 520 nm photons must be absorbed by the photovoltaic cell in order to heat 10.0 g of water from 20.0°C to 30.0°? [Given: The specific heat of water is 4.184 J/g·°C.]

A. 4.12×10^{20}
B. 1.72×10^{21}
C. 2.62×10^{20}
D. 6.95×10^{20}
E. 1.10×10^{21}

72. Write the ground state electron configuration for the selenium atom.

73. Write the ground state electron configuration for the phosphorus atom.

74. Calculate the energy of a photon of light with a wavelength of 360 nm.

75. What is the difference in the electron configuration between carbon-14 and carbon-12?

76. With regard to electron behavior, what happens when light is absorbed or emitted by an atom?

77. What is the total number of electrons possible in the 2*p* orbitals?

78. What is the total number of electrons possible in the 6*s* orbital?

79. What is the ground-state electron configuration for chlorine?

80. If one electron is added to the outer shell of chlorine, to which element would the configuration be similar?

81. What is the electron configuration of calcium?

82. If we take away two electrons from the outer shell of calcium, to which element would the structure be similar?

83. The colors of the visible spectrum are red, orange, yellow, green, blue, and violet.
Of these colors, _______ has the most energy.

84. The colors of the visible spectrum are red, orange, yellow, green, blue, and violet.
Of these colors, ______ has the least energy.

85. What is the outermost electron configuration of O?

86. What is the outermost electron configuration of S?

87. What is the outermost electron configuration of Se?

88. What is the outermost electron configuration of Te?

89. What is the outermost electron configuration of Be?

90. What is the outermost electron configuration of Mg?

91. What is the outermost electron configuration of Ca?

92. What is the outermost electron configuration of Sr?

93. What is the wavelength, in meters, of an alpha particle with a kinetic energy of 8.0×10^{-13} J. [mass of an alpha particle = 4.00150 amu; 1 amu = 1.67×10^{-27} kg]

94. What is the wavelength of a ball bearing with a mass of 10.0 g, and a velocity of 10.0 cm/s?

95. The bonds of oxygen molecules are broken by sunlight. The minimum energy required to break the oxygen-oxygen bond is 495 kJ/mol. What is the wavelength of sunlight that can cause this bond breakage?

96. The Bohr model of the hydrogen atom found its greatest support in experimental work on the photoelectric effect.

True False

97. An electron in a 3*p* orbital could have a value of 2 for its angular momentum quantum number (l).

True False

98. A neon atom in its ground state will be diamagnetic.

True False

99. Each shell (principal energy level) of quantum number *n* contains *n* subshells.

True False

100. For all atoms of the same element, the 2*s* orbital is larger than the 1*s* orbital.

True False

101. According to de Broglie's equation, the wavelength associated with the motion of a particle increases as the particle mass decreases.

True False

102. The frequency of the emitted light from a cesium atom is an *intensive* property.

True False

Chapter 7 Quantum Theory and the Electronic

Structure of **Atoms Key**

1.B

2.D

3.C

4.A

5.C

6.E

7.B

8.A

9.C

10.C

11.E

12.E

13.A

14.A

15.B

16.D

17.A

18.D

19.E

20.B

21.E

22.A

23.D

24.B

25.B

26.B

27.C

28.C

29.B

30.D

31.D

32.D

33.A

34.A

35.D

36.D

37.C

38.A

39.C

40.B

41.B

42.A

43.A

44.C

45.E

46.E

47.D

48.D

49.B

50.D

51.C

52.E

53.C

54.D

55.B

56.E

57.C

58.D

59.A

60.A

61.E

62.B

63.A

64.B

65.E

66.D

67.C

68.A

69.D

70.E

71.B

72.[Ar] $4s^2 3d^{10} 4p^4$

73.[Ne] $3s^2 3p^3$

74.5.5 × 10^{-19} J

75.There is no difference.

76.The electrons move between orbitals.

77.6

78.2

79.$1s^2 2s^2 2p^6 3s^2 3p^5$ *or* [Ne]$3s^2 3p^5$

80.Argon

81.$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ *or* [Ar]$4s^2$

82.Argon

83.violet

84.red

85.$2s^2 2p^4$

86.$3s^2 3p^4$

87.$4s^2 3d^{10} 4p^4$

88.$5s^2 4d^{10} 5p^4$

89.$2s^2$

90.$3s^2$

91.$4s^2$

92.$5s^2$

93.6.4 × 10^{-15} m

94.6.63 × 10^{-22} nm

95.242 nm

96.FALSE

97.FALSE

98.TRUE

99.TRUE

100.TRUE

101.TRUE

102.TRUE