Chapter 1: The Quantum World

1. Visible light, microwaves, and x-rays travel through empty space at 3.00×10^8 m·s^{-1}. True or false?

   Ans: True

2. Which of the following statements regarding electromagnetic radiation is true?
   A) Electromagnetic radiation with a wavelength of 400 nm travels faster than that with a wavelength of 600 nm.
   B) The frequency of electromagnetic radiation determines how fast it travels.
   C) Electromagnetic radiation with a wavelength of 400 nm has a frequency that is smaller than that with a wavelength of 600 nm.
   D) Electromagnetic radiation with a wavelength of 600 nm travels faster than that with a wavelength of 400 nm.
   E) Electromagnetic radiation with a wavelength of 600 nm has a frequency that is smaller than that with a wavelength of 400 nm.

   Ans: E

3. Electromagnetic radiation encompasses which of the following?
   A) Microwaves.
   B) Alpha particles.
   C) Gamma radiation.
   D) A and C above.
   E) B and C above.

   Ans: D

4. Which of the following statements is the highest frequency electromagnetic radiation?
   A) X-radiation.
   B) Ultraviolet.
   C) Visible light.
   D) Microwave.
   E) Radio.

   Ans: A

5. Which of the following is the smallest wavelength electromagnetic radiation?
   A) Radio.
   B) Microwave.
   C) Ultraviolet.
   D) Visible blue light.
   E) Infrared.

   Ans: C

6. The ultraviolet range encompasses what wavelengths?
   A)   100 – 450nm.
   B)   530 – 580 nm.
   C)   1 – 50 nm.
   D)   10 – 80 nm.
   E)   420 – 500 nm.
   Ans: A

7. Wavelength is defined how, in terms of electromagnetic radiation?
   A)   The peak to peak distance between waves.
   B)   The peak to trough distance between waves.
   C)   The speed with which a wave traverses a distance.
   D)   The amplitude with which a wave traverses a distance.
   E)   The trough to peak distance between a wave as well as the speed the wave
         traverses this distance.
   Ans: A

8. Which of the following statements regarding electromagnetic radiation is true?
   A)   Electromagnetic radiation with a wavelength of 800 nm is in the ultraviolet range.
   B)   Electromagnetic radiation with a wavelength of 900 nm is in the visible light
         range.
   C)   Electromagnetic radiation with a wavelength of 400 nm is in the visible light
         range.
   D)   Electromagnetic radiation with a wavelength of 600 nm is in the ultraviolet range.
   E)   Electromagnetic radiation with a wavelength of 600 nm is in the visible light
         range.
   Ans: E

9. Radiation with a wavelength of 2 – 10 pm is in what part of the electromagnetic
   spectrum?
   A)   Radio waves.
   B)   Microwave radiation.
   C)   Ultraviolet radiation.
   D)   X – radiation.
   E)   Gamma radiation.
   Ans: D

10. Radiation with a wavelength of 2.2 mm is most likely in what part of the
    electromagnetic spectrum?
    A)   Cosmic rays.
    B)   X – rays.
    C)   Microwaves.
    D)   Ultraviolet radiation.
    E)   Gamma radiation.
    Ans: C

11. What is the frequency of yellow light with a wavelength of 580 nm?

    A) 5.2×10^{16} Hz   D) 5.2×10^{12} Hz
    B) 1.9×10^{-17} Hz   E) 1.9×10^{-15} Hz
    C) 5.2×10^{14} Hz

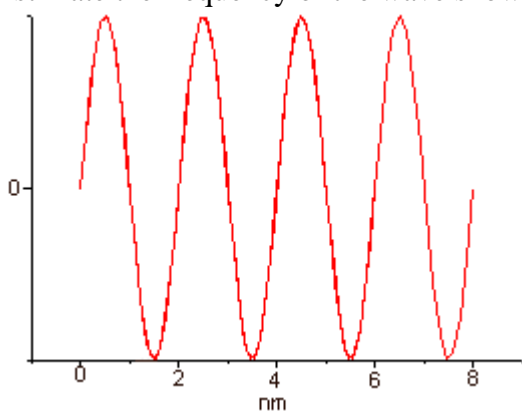   Ans: C

12. What is the wavelength of a radio station transmitting at 99.1 MHz?

    A) 330 nm   B) 303 nm   C) 0.00303 m   D) 3.03 m   E) 0.330 m

    Ans: D

13. Estimate the frequency of the wave shown below.

    A) 1.5×10^{17} s^{-1}
    B) 3.0×10^{17} s^{-1}
    C) 1.0×10^{17} s^{-1}
    D) 2.0×10^{17} s^{-1}
    E)   Not enough information is given to permit calculation of the frequency.

    Ans: A

14. Which of the following has the highest energy per photon?
    A)   Infrared
    B)   Blue light
    C)   Green light
    D)   Orange light
    E)   Red light
    Ans: E

15. What is the wavelength of radiation with a frequency of 2.3×10^{13} /sec?
    A) 3.0×10^8 m
    B) 7.6×10^5 cm
    C) 7.6×10^5 m
    D) 1.3×10^{-5} cm
    E) 1.3×10^{-5} m
    Ans: E

16. Radiation with a frequency of 3.9×10^{14}/sec has what wavelength?
    A) 1.3×10^6 m
    B) 7.7×10^{-7} cm
    C) 7.7×10^{-7} m
    D) 3.1×10^6 m
    E) 1.3×10^6 cm
    Ans: C

17. What wavelength does radiation possess when its frequency is 2.1×10^{15} Hz?
    A) 4.1×10^{-7} cm
    B) 1.4×10^{-7} m
    C) 6.5×10^6 m
    D) 7.0×10^6 m
    E) 1.4×10^{-7} nm
    Ans: B

18. What wavelength does radiation have when its frequency is 5.6×10^{13} /sec?
    A) 5.4×10^{-9} m
    B) 5.4×10^{-8} m
    C) 5.4×10^{-7} m
    D) 5.4×10^{-6} m
    E) 5.4×10^{-6} cm
    Ans: D

19. When radiation has a frequency of 6.9×10^{17} Hz, what is its wavelength?
    A) 4.3×10^{-10} m
    B) 3.4×10^{-10} m
    C) 3.0×10^{-8} m
    D) 2.3×10^{-9} m
    E) 2.3×10^{-8} nm
    Ans: A

20. What is the wavelength of radiation with a frequency of 1.1×10^{11} /sec?
    A) 3.7×10^{2} m
    B) 2.7×10^{-3} cm
    C) 2.7×10^{-3} m
    D) 3.7×10^{2} cm
    E) 2.7×10^{-13} m
    Ans: C

21. What is the frequency of radiation with a wavelength of 2.0 m?
    A) 1.5×10^{8} /sec
    B) 3.0×10^{8} /sec
    C) 7.0×10^{-9} /sec
    D) 7.0×10^{8} /sec
    E) 1.5×10^{-8} /sec
    Ans: A

22. When radiation has a frequency of 1.5×10^{15} Hz, what is its wavelength?
    A) 3.0×10^{-11} m
    B) 4.2×10^{-7} m
    C) 2.0×10^{-7} cm
    D) 2.0×10^{-7} m
    E) 2.0×10^{-8} m
    Ans: D

23. What is the wavelength of radiation with a frequency of 2.7×10^{18} m?
    A) 1.1×10^{-11} cm
    B) 1.1×10^{-11} m
    C) 9.9×10^{-11} m
    D) 9.9×10^{-11} cm
    E) 3.0×10^{-11} m
    Ans: B

24. If radiation has a frequency of 3.1×10^{16} sec^{-1}, what is its wavelength?
    A) 1.0×10^8 cm
    B) 1.0×10^{-8} cm
    C) 1.0×10^8 m
    D) 1.0×10^{-8} m
    E) 3.0×10^{-8} m
    Ans: D

25. What is the wavelength of radiation that has a frequency of 4.9×10^{13} /sec?
    A) 6.1×10^{-6} m
    B) 6.1×10^{-6} cm
    C) 6.1×10^6 m
    D) 1.6×10^5 m
    E) 1.6×10^{-5} m
    Ans: A

26. When radiation has a frequency of 5.2×10^{12} Hz, what is its wavelength?
    A) 5.8×10^{-5} cm
    B) 1.7×10^4 m
    C) 1.7×10^{-4} m
    D) 5.8×10^{-5} m
    E) 5.8×10^5 m
    Ans: D

27. What magnitude of wavelength and frequency does X-radiation have?
    A) Small wavelength and low frequency.
    B) Small wavelength and high frequency.
    C) Large wavelength and low frequency.
    D) Large wavelength and high frequency.
    E) Wavelength almost the same as that in visible light.
    Ans: B

28. How is gamma radiation best described?
    A) As very small wavelength and low frequency.
    B) As wavelength very near that of the visible spectrum.
    C) As large wavelength.
    D) As very low frequency.
    E) As very high frequency.
    Ans: E

29. What type of wavelength is characteristic of radio waves?
    A)   Very large.
    B)   Very small.
    C)   Large or small depending on frequency.
    D)   Close to that of visible light.
    E)   None of the above; radio waves are not a form of radiation.
    Ans: A

30. What is the general wavelength of visible light?
    A)   1 – 100 nm
    B)   100 – 400 nm
    C)   420 – 700 nm
    D)   750 – 1,000 nm
    E)   > 1,000 nm
    Ans: C

31. Which of the following has the highest frequency?
    A)   Microwave radiation
    B)   Infrared radiation
    C)   Visible light
    D)   Ultraviolet radiation
    E)   X-rays
    Ans: E

32. Which of the following has the largest wavelengths?
    A)   Red visible light
    B)   Blue visible light
    C)   Microwaves
    D)   Ultraviolet radiation
    E)   Gamma radiation
    Ans: C

33. Of the following, which wavelength range is visible to the human eye?
    A)   950 nm
    B)   870 nm
    C)   770 nm
    D)   500 nm
    E)   380 nm
    Ans: D

34. Which of the following corresponds to an X-radiation wavelength?
    A)   0.0001 nm
    B)   0.001 nm
    C)   9 cm
    D)   9 nm
    E)   95 nm
    Ans: D

35. Which of the following is a Lyman series UV band?
    A)   121.6 nm
    B)   221.6 nm
    C)   434.0 nm
    D)   121.6 cm
    E)   410.2 nm
    Ans: A

36. Of the following, which is a Balmer series visible band?
    A)   954.6 nm
    B)   656.3 nm
    C)   401.2 nm
    D)   121.6 nm
    E)   97.3 nm
    Ans: B

37. Which of the following is a Lyman series line?
    A)   954.6 nm
    B)   656.3 nm
    C)   486.1 nm
    D)   434.0 nm
    E)   None of the above.
    Ans: E

38. What is implied about an electron in an atom when it is observed that it has discrete spectral lines?
    A)   The electron is negatively charged.
    B)   The electron is oppositely charged from the proton.
    C)   The electron circles the nucleus.
    D)   The electron can have only certain energies.
    E)   The electron has negligible mass.
    Ans: D

39. What does the term "black body" signify for an object?
    A)   The object is white hot.
    B)   The object is black to human sight.
    C)   The object absorbs and emits all wavelengths
    D)   The object absorbs certain wavelengths of light preferentially.
    E)   There is no significance to the name.
    Ans: C

40. In 1.0 s, a 60 W bulb emits 11 J of energy in the form of infrared radiation (heat) of wavelength 1850 nm. How many photons of infrared radiation does the lamp generate in 1.0 s?
    A) 1.0×10^{29} B) 1.0×10^{20} C) 6.8×10^{-14} D) 1.1×10^{-19} E) 6.6×10^{23}
    Ans: B

41. What is the energy in joules of a photon with a frequency of 5.6×10^{14} Hz?
    A) 3.7×10^{-21} B) 6.8×10^{20} C) 6.8×10^{-19} D) 3.7×10^{-19} E) 3.7×10^{19}
    Ans: D

42. How many joules of energy does a photon have with a frequency of 6.8×10^{15} Hz?
    A) 4.5×10^{28} B) 5.6×10^{-18} C) 4.5×10^{-18} D) 5.6×10^{-19} E) 4.5×10^{-23}
    Ans: C

43. A photon with a frequency of 2.3×10^{16} Hz has how many joules of energy?
    A) 1.5×10^{-17} B) 1.5×10^{17} C) 3.5×10^{-17} D) 3.5×10^{17} E) 3.0×10^8
    Ans: A

44. What energy in joules does a photon with a frequency of 5.0×10^{14} /sec have?
    A) 1.3×10^{-19} B) 3.3×10^{-19} C) 6.6×10^{-19} D) 6.6×10^{19} E) 3.3×10^{19}
    Ans: B

45. A photon with a frequency of 1.2×10^{15} Hz has what energy?
    A) 8.0×10^{-19} B) 1.0×10^{-19} C) 8.0×10^{19} D) 5.5×10^{-49} E) 5.5×10^{49}
    Ans: A

46. What is the frequency, in Hz, of a photon with energy of 2.3×10^{-17} J?
    A) 3.4×10^{-16} B) 3.4×10^{16} C) 6.8×10^{-16} D) 6.8×10^{16} E) 2.8×10^{-15}
    Ans: B

47. A photon with energy of 3.9×10^{-17} J has what frequency, in /sec?
    A) 6.6×10^{-34} B) 3.7×10^{15} C) 3.7×10^{-15} D) 2.7×10^{14} E) 2.7×10^{-14}
    Ans: D

48. What is the frequency of a photon that has an energy of 5.4×10^{-18} J?
    A) 1.6×10^{-34}Hz   B) 1.2×10^{16}Hz   C) 1.2×10^{-16}Hz   D) 8.1×10^{15}Hz   E) 8.1×10^{15}Hz
    Ans: E

49. A photon with an energy of 1.8×10^{-19} J possesses what frequency in sec^{-1}?
    A) 7.2×10^{-14} B) 2.7×10^{15} C) 2.7×10^{-14} D) 2.7×10^{14} E) 7.2×10^{15}
    Ans: D

50. If a photon has an energy of 4.0×10^{-16} J, what will its frequency be, in Hz?
    A) 6.0×10^{17} B) 6.0×10^{16} C) 3.9×10^{17} D) 1.8×10^{-17} E) 1.3×10^{20}
    Ans: A

51. When a photon has an energy of 1.3×10^{-20} J, what will its frequency be, in Hz?
    A) 1.9×10^{14} B) 9.1×10^{20} C) 1.9×10^{13} D) 9.1×10^{-19} E) 6.0×10^{13}
    Ans: C

52. What is the energy of a photon with a frequency of 3.8×10^{14} Hz?
    A) 1.5×10^{-15}J   B) 3.8×10^{14}J   C) 8.3×10^{-14}J   D) 3.8×10^{-19}J   E) 1.5×10^{-15}J
    Ans: B

53. What is the energy of a mole of photons with a frequency of 1.2×10^{14} Hz?
    A) 4.8×10^{-4}J/mol   B) 3.8×10^{4}J/mol   C) 4.8×10^{4}J/mol   D) 3.8×10^{-4}J/mol
    E) 8.4×10^{5}J/mol
    Ans: C

54. What is the energy of a mole of photons with a frequency of 3.8×10^{14} /sec?
    A) 1.5×10^{5}J/mol   B) 1.5×10^{-5}J/mol   C) 6.7×10^{-7}J/mol   D) 6.7×10^{7}J/mol
    E) 3.8×10^{-5}J/mol
    Ans: A

55. When a mole of photons has the frequency 4.2×10^{15} Hz, what is its energy?
    A) 1.7×10^{-6}J/mol   B) 5.9×10^{-7}J/mol   C) 5.9×10^{7}J/mol   D) 6.2×10^{8}J/mol
    E) 1.7×10^{6}J/mol
    Ans: E

56. What is the energy of a mole of photons with a frequency of 2.9×10^{15} sec^{-1}?
    A) 1.2×10^{6}J/mol   B) 1.2×10^{9}J/mol   C) 8.3×10^{-7}J/mol   D) 8.3×10^{7}J/mol
    E) 6.7×10^{6}J/mol
    Ans: A

57. What is the energy of a mole of photons with a frequency of 3.2×10^{16} Hz?
    A) 1.3×10^7J/mol B) 1.3×10^{-7}J/mol C) 3.2×10^{16}J/mol D) 7.7×10^{-8}J/mol
    E) 7.7×10^8J/mol
    Ans: A

58. A mole of photons with a frequency of 7.5×10^{16} Hz has what energy?
    A) 3.0×10^{-7}J/mol B) 4.2×10^6J/mol C) 3.3×10^{-8}J/mol D) 3.0×10^7J/mol
    E) 3.3×10^8J/mol
    Ans: D

59. What is the energy of a mole of photons with a frequency of 6.9×10^{14} Hz?
    A) 2.8×10^5J/mol B) 8.3×10^4J/mol C) 8.3×10^{-4}J/mol D) 3.8×10^6J/mol
    E) 2.8×10^{-6}J/mol
    Ans: A

60. A mole of photons with a frequency of 3.1×10^{14} /sec has what energy?
    A) 1.2×10^{-5}J/mol B) 8.3×10^{-7}J/mol C) 8.3×10^7J/mol D) 7.1×10^7J/mol E) 1.2×10^5J/mol
    Ans: E

61. What is the energy of a mole of photons with a frequency of 5.8×10^{15} sec^{-1}?
    A) 2.3×10^{-5}J/mol B) 2.3×10^6J/mol C) 4.9×10^6J/mol D) 4.9×10^{-5}J/mol
    E) 5.8×10^{-15}J/mol
    Ans: B

62. What is the energy of a mole of photons with a frequency of 9.1×10^{15} Hz?
    A) 3.6×10^{-5}J/mol B) 3.6×10^6J/mol C) 2.8×10^{-7}J/mol D) 2.8×10^7J/mol
    E) 7.0×10^6J/mol
    Ans: B

63. When a mole of photons has the energy 3.3×10^7 J, what is its frequency, in Hz?
    A) 2.6×10^{-15} B) 2.6×10^{16} C) 8.2×10^{-15} D) 8.2×10^{16} E) 13.3×10^{-7}
    Ans: D

64. When a mole of photons possesses an energy of 2.4×10^7 J, what is its frequency in /sec?
    A) 1.6×10^{-15}J/mol B) 6.1×10^{-16}J/mol C) 6.1×10^{16}J/mol D) 1.6×10^5J/mol
    E) 4.2×10^{16}J/mol
    Ans: C

65. A lawyer who received a speeding ticket argues that because of the Heisenberg uncertainty principle the radar reading is uncertain. The judge, who happens to have a science degree, rules against the lawyer. Which of the following statements is true?
    A) The judge is incorrect because the uncertainty in position is large.
    B) The judge is correct because the car is so massive that the uncertainty in speed is very small.
    C) The judge is correct because the uncertainty in momentum is very large.
    D) The judge is incorrect because radar has only wave characteristics.
    E) The judge is incorrect because $(m\Delta v)(\Delta x) \geq \dfrac{1}{2}h.$

    Ans: B

66. Calculate the wavelength of a motorcycle of mass 275 kg traveling at a speed of 125 km·hr^{-1}.
    A) 6.94×10^{-38} m
    B) 1.93×10^{-38} m
    C) 1.93×10^{-41} m
    D) 2.41×10^{-36} m
    E) 2.08×10^{-29} m

    Ans: A

67. You are caught in a radar trap and hope to show that the speed measured by the radar gun is in error because of the uncertainty principle. If you assume that the uncertainty in your position is large, say about 10 m, and that the car has a mass of 2150 kg, what is the uncertainty in the velocity?
    A) 1×10^{-33} m·s^{-1}
    B) 1×10^{-19} m·s^{-1}
    C) 1×10^{33} m·s^{-1}
    D) 1×10^{38} m·s^{-1}
    E) 1×10^{-38} m·s^{-1}

    Ans: E

68. In everyday life, we have no difficulty in measuring both the velocity and position of objects. True or false?
    Ans: True

69. Light of wavelength 242 nm ionizes a sodium ion in the gas phase; what is the ionization energy of sodium?
    A) 8.20 kJ·mol^{-1} B) 988 kJ·mol^{-1} C) 198 kJ·mol^{-1} D) 494 kJ·mol^{-1} E) 247 kJ·mol^{-1}
    Ans: D

70. Calculate the velocity of an oxygen molecule, given that it has a de Broglie wavelength of 0.0140 nm.
    A) 890. m·s^{-1}
    B) 3.00×10^{8} m·s^{-1}
    C) 1780 m·s^{-1}
    D) 445 m·s^{-1}
    E) 8.90 m·s^{-1}

    Ans: A

71. Which of the following experiments most directly supports de Broglie's hypothesis of the wave nature of matter?
    A)   Black-body radiation
    B)   The photoelectric effect
    C) α-particle scattering by a metal foil
    D)   Electron diffraction by a crystal
    E)   The emission spectrum of the hydrogen atom
    Ans: D

72. The Bohr radius for an electron in the ground state of a hydrogen atom is 52.9 pm. The Bohr radius for an electron in the $n = 2$ state of He^+ is
    A) 211.6 pm.   B) 105.8 pm.   C) 26.5 pm.   D) 52.9 pm.   E) 13.2 pm.
    Ans: B

73. The first line (lowest energy) in the Balmer series appears at 15,233 cm^{-1}. The second line appears at
    A)   109,678 cm^{-1}.   D)   30,466 cm^{-1}.
    B)   45,699 cm^{-1}.   E)   20,311 cm^{-1}.
    C)   20,565 cm^{-1}.
    Ans: C

74. In a one-dimensional particle in a box, for $n = 6$, how many wavelengths equal the size of the box?
    A) 0   B) 3   C) 1   D) 12   E) 6
    Ans: B

75. In a one-dimensional particle in a box, for Ψ_4, how many nodes are predicted?
    A) 1   B) 3   C) 0   D) 2   E) 4
    Ans: B

76. In a one-dimensional particle in a box, the zero-point energy corresponds to
    A)   a node.
    B) $n = 0$.
    C) $n = 1$.
    D)   A quantum state where the uncertainty principle is not valid.
    E) $\Psi^2 = 0$.
    Ans: C

77. If an electron is confined to a one-dimensional box 200 pm in length, calculate the zero-point energy.
    A) 1.51×10^{-18} J   D) 1.21×10^{-19} J
    B) 6.04×10^{-18} J   E) 1.21×10^{-17} J
    C) 1.51×10^{-20} J
    Ans: A

78. An electron is confined to a one-dimensional box 200 pm in length, calculate the wavelength of light required to promote the electron from the ground state to the first excited state.
    A) 329 pm   B) 263 pm   C) 165 pm   D) 439 pm   E) 1320 pm
    Ans: D

79. Which of the following statements is incorrect?
    A)   For a one-dimensional particle in a box, as the mass of the particle becomes larger the separation between neighboring energy levels increases.
    B)   For a one-dimensional particle in a box, the separation between neighboring energy levels increases as the length of the container increases.
    C)   For a one-dimensional particle in a box, the energy separation between neighboring energy levels has the value $h^2/8mL^2$ when the walls of the box are infinitely far apart.
    D)   Argon atoms in a cylinder can be treated as though their translational energy were quantized.
    E)   A billiard ball on a table has a completely negligible zero-point energy.
    Ans: E

80. If a particle is confined to a one-dimensional box of length 300 pm, for Ψ_3 the particle has zero probability of being found at
    A)   100 and 200 pm, respectively.
    B)   150 pm only.
    C)   50, 150, and 250 pm, respectively.
    D)   50 and 250 pm, respectively.
    E)   75, 125, 175, and 225 pm, respectively.
    Ans: A

81. If a particle is confined to a one-dimensional box of length 300 pm, for Ψ_3 the particle is most likely to be found at
    A)   0 pm.   D)   300 pm.
    B)   50, 150, and 250 pm, respectively. E)   100 and 200 pm, respectively.
    C)   17.3 pm.
    Ans: B

82. What is the probability of finding an electron in a small region of a hydrogen 1s orbital at a distance $3a_0$ from the nucleus relative to the probability of finding it in the same small region located at the nucleus?
    A) 14%   B) 0.25%   C) 22%   D) 1.8%   E) 5.0%
    Ans: B

83. Which of the following emission lines corresponds to part of the Balmer series of lines in the spectrum of a hydrogen atom?
    (a) $n_2 \rightarrow n_1$
    (b) $n_4 \rightarrow n_2$
    (c) $n_4 \rightarrow n_1$
    (d) $n_3 \rightarrow n_2$
    (e) $n_4 \rightarrow n_3$
    A) (b) and (d)   B) (a), (d), and (e)   C) (a) and (c)   D) (e)   E) (b) and (c)
    Ans: A

84. Calculate the longest-wavelength line in the Balmer series for hydrogen.
    A) 182 nm   B) 657 nm   C) 536 nm   D) 122 nm   E) 486 nm
    Ans: B

85. The Balmer series of lines for the hydrogen atom are found only in the visible region of the spectrum. True or false?
    Ans: False

86. What is the shortest-wavelength line in the emission spectrum of the hydrogen atom?
    A) 182 nm   B) 100 nm   C) 122 nm   D) 91.2 nm   E) 1.00 nm
    Ans: D

87. Which of the following statements with respect to the photoelectric effect is incorrect?
    A)   A plot of the kinetic energy of the ejected electrons versus the frequency of the incident radiation has a slope that is equal to the value of the work function.
    B)   All metals have a unique work function.
    C)   The kinetic energy of the ejected electrons does not increase with the intensity of the incident radiation.
    D)   A plot of the kinetic energy of the ejected electrons versus the frequency of the incident radiation is linear.
    Ans: A

88. Which of the following is expected to approximate the value of the wavelength of a 5-g bullet traveling at 1300 miles per hour?
    A) 2 m   B) 2×10^{-34} m   C) 200 pm   D) 2 pm
    Ans: B

89. Estimate the minimum uncertainty in the position of an electron of mass 9.109×10^{-31} kg, given that its speed is unknown to within $\pm 3.00 \times 10^5 \text{m·s}^{-1}$.
    A) 386 pm   B) 386×10^{-12} m   C) 193 pm   D) 1.93×10^{-12}
    Ans: C

90. The four π electrons of 1,3-butadiene can be modeled as particles in a box. If the length of 1,3-butadiene (L) is 0.56 nm, calculate the energy of the lowest energy transition.
    Ans: 9.6×10^{-19} J

91. Carotene, which is partly responsible for the color of carrots, has 22 π electrons in a conjugated system and a length of about 3 nm. The lowest energy transition in carotene is from $n =$ ___ to $n =$ ___.
    Ans: 11; 12

92. Comparing the lowest energy transition, ΔE, in 1,3-butadiene(A) and 1,3,5,7-octatetraene(B), ΔE_A is greater than ΔE_B. True or false?
    Ans: True

93. The zero-point energy in 1,3-butadiene is larger than in 1,3,5,7-octatetraene. True or false?
    Ans: True

94. Which of the following metals has the lowest work function?
    A) Be   B) Sr   C) Li   D) Rb
    Ans: D

95. The square of the amplitude of a wave determines the intensity of the radiation. True or false?
    Ans: True

96. A node is a point at which the wavefunction becomes zero. True or false?
    Ans: False

97. The planet Mercury has a maximum intensity of solar radiation of 3700 nm on the sunlit side. What is the temperature of the surface of Mercury on the sunlit side? The empirical value of the constant in Wien's law is 2.9 K·mm.
    A)   510ºC
    B)   780ºC
    C)   1100ºC
    D)   290ºC
    E)   543ºC
    Ans: A

98. Which of the following is Wien's law?
    A) The maximum intensity of black-body radiation, λ_{max}, is inversely proportional to the temperature.
    B) λ_{max} = constant × T where λ_{max} is the intensity of black-body radiation and T is the temperature in K.
    C) λ_{max} = constant × T^4 where λ_{max} is the intensity of black-body radiation and T is the temperature in K.
    D) The maximum intensity of black-body radiation, λ_{max}, increases as the temperature increases.
    E) T = 2.9 K.mm × λ_{max} where λ_{max} is the intensity of black-body radiation and T is the temperature in K.

    Ans: A

99. Consider a one-dimensional particle in a box of length $2L$ and one of length $3L$. Which of the following is true?
    A) The energy levels $n = 1$ and $n = 2$ are closer together for the box of length $3L$.
    B) The energy levels $n = 1$ and $n = 2$ are closer together for the box of length $2L$.
    C) The energy levels for the box of length $3L$ are all higher than those for the box of length $2L$.
    D) The zero-point energy of the two boxes is the same.
    E) The zero-point energy of the box of length $2L$ is smaller than that of the box of length $3L$.

    Ans: A

100. All the orbitals of a given shell of He^+ are degenerate regardless of the value of the orbital angular momentum. True or false?
    Ans: True