Chapter 40: ALL ABOUT ATOMS

1. The magnitude of the orbital angular momentum of an electron in an atom is what multiple of $\hbar$? (ℓ is a positive integer.)
   A. 1
   B. 1/2
   C. $\sqrt{\ell(\ell+1)}$
   D. $2\ell+1$
   E. ℓ^2
   ans: C

2. The magnetic quantum number m_ℓ is most closely associated with what property of an electron in an atom?
   A. Magnitude of the orbital angular momentum
   B. Energy
   C. z component of the spin angular momentum
   D. z component of the orbital angular momentum
   E. Radius of the orbit
   ans: D

3. The quantum number m_s is most closely associated with what property of the electron in an atom?
   A. Magnitude of the orbital angular momentum
   B. Energy
   C. z component of the spin angular momentum
   D. z component of the orbital angular momentum
   E. Radius of the orbit
   ans: C

4. Possible values of the principal quantum number n for an electron in an atom are:
   A. only 0 and 1
   B. only 0, 1, 2, $\ldots$, ∞
   C. only 0, 1, $\ldots$, $\ell-1$
   D. only 1/2 and $-1/2$
   E. only 1, 2, 3, $\ldots$, ∞
   ans: E

5. The number of values of the orbital quantum number ℓ associated with the principal quantum number $n=3$ is:
   A. 1
   B. 2
   C. 3
   D. 4
   E. 7
   ans: C

6. The number of possible values of the magnetic quantum number m_ℓ associated with a given value of the orbital quantum number ℓ is:
   A. 1
   B. 2
   C. ℓ
   D. 2ℓ
   E. $2\ell + 1$
   ans: E

7. An atom is in a state with orbital quantum number $\ell = 2$. Possible values of the magnetic quantum number m_ℓ are:
   A. 1, 2
   B. 0, 1, 2
   C. 0, 1
   D. -1, 0, 1
   E. -2, -1, 0, 1, 2
   ans: E

8. An electron is in a quantum state for which the magnitude of the orbital angular momentum is $6\sqrt{2}\hbar$. How many allowed values of the z component of the angular momentum are there?
   A. 4
   B. 5
   C. 7
   D. 8
   E. 9
   ans: D

9. An electron is in a quantum state for which there are seven allowed values of the z component of the angular momentum. The magnitude of the angular momentum is:
   A. $\sqrt{3}\hbar$
   B. $\sqrt{7}\hbar$
   C. $\sqrt{9}\hbar$
   D. $\sqrt{12}\hbar$
   E. $\sqrt{14}\hbar$
   ans: D

10. The number of states in a subshell with orbital quantum number $\ell = 3$ is:
   A. 2
   B. 3
   C. 7
   D. 9
   E. 14
   ans: E

11. The number of states in a shell with principal quantum number $n = 3$ is:
 A. 3
 B. 9
 C. 15
 D. 18
 E. 25
 ans: D

12. An electron in an atom is in a state with principal quantum number $n = 4$. The possible values of the orbital quantum number ℓ are:
 A. 1, 2, 3
 B. 1, 2, 3, 4
 C. $-3, -2, -1, 0, 1, 2, 3$
 D. 0, 1, 2, 3
 E. 0, 1, 2
 ans: D

13. Space quantization means that:
 A. space is quantized
 B. L_z can have only certain discrete values
 C. $\vec{L}$ and $\vec{\mu}$ are in the same direction
 D. $\vec{L}$ and $\vec{\mu}$ are in opposite directions
 E. an electron has a magnetic dipole moment
 ans: B

14. An electron in an atom is in a state with $\ell = 3$ and $m_\ell = 2$. The angle between $\vec{L}$ and the z axis is:
 A. 48.2°
 B. 60°
 C. 30°
 D. 35.3°
 E. 54.7°
 ans: E

15. An electron in an atom is in a state with $\ell = 5$. The minimum angle between $\vec{L}$ and the z axis is:
 A. 0°
 B. 18.0°
 C. 24.1°
 D. 36.7°
 E. 33.6°
 ans: C

16. In the relation $\mu_z = -m_\ell \mu_B$, the quantity μ_B is:

A. the Bohr magneton
B. the component of the dipole moment along the magnetic field
C. the permeability of the material
D. a friction coefficient
E. none of the above

ans: A

17. The electron states that constitute a single shell for an atom all have:

A. the same value of n
B. the same value of ℓ
C. the same value of n and the same value of ℓ
D. the same value of ℓ and the same value of m_ℓ
E. the same set of all four quantum numbers

ans: A

18. The electron states that constitute a single subshell for an atom all have:

A. only the same value of n
B. only the same value of ℓ
C. only the same value of n and the same value of ℓ
D. only the same value of ℓ and the same value of m_ℓ
E. the same set of all four quantum numbers

ans: C

19. The total number of electron states with $n = 2$ and $\ell = 1$ for an atom is:

A. two
B. four
C. six
D. eight
E. ten

ans: C

20. The possible values for the magnetic quantum number m_s of an electron in an atom:

A. depend on n
B. depend on ℓ
C. depend on both n and ℓ
D. depend on whether there is an external magnetic field present
E. are $\pm 1/2$

ans: E

21. The Stern-Gerlach experiment makes use of:

A. a strong uniform magnetic field
B. a strong non-uniform magnetic field
C. a strong uniform electric field
D. a strong non-uniform electric field
E. strong perpendicular electric and magnetic fields

ans: B

22. The magnetic field $\vec{B}$ is along the z axis in a Stern-Gerlach experiment. The force it exerts on a magnetic dipole with dipole moment $\vec{\mu}$ is proportional to:

A. μ_z^2
B. B^2
C. dB/dz
D. d^2B/dz^2
E. $\int B\,dz$

ans: C

23. A magnetic dipole $\vec{\mu}$ is placed in a strong uniform magnetic field $\vec{B}$. The associated force exerted on the dipole is:

A. along $\vec{\mu}$
B. along $-\vec{\mu}$
C. along $\vec{B}$
D. along $\vec{\mu} \times \vec{B}$
E. zero

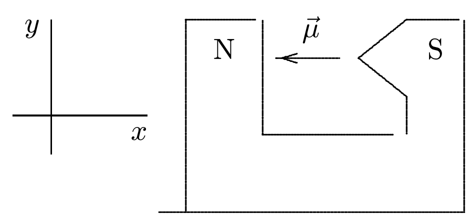
ans: E

24. The force exerted on a magnetic dipole as it moves with velocity $\vec{v}$ through a Stern-Gerlach apparatus is:

A. proportional to v
B. proportional to $1/v$
C. zero
D. proportional to v^2
E. independent of v

ans: E

25. A magnetic dipole is placed between the poles of a magnet as shown. The direction of the associated force exerted on the dipole is:



A. positive x
B. positive y
C. negative x
D. negative y
E. into or out of the page

ans: C

26. To observe the Zeeman effect one uses:
   A. a strong uniform magnetic field
   B. a strong non-uniform magnetic field
   C. a strong uniform electric field
   D. a strong non-uniform electric field
   E. mutually perpendicular electric and magnetic fields

   ans: B

27. An electron in a K shell of an atom has the principal quantum number:
   A. $n = 0$
   B. $n = 1$
   C. $n = 2$
   D. $n = 3$
   E. $n = \infty$

   ans: B

28. An electron in an L shell of an atom has the principal quantum number:
   A. $n = 0$
   B. $n = 1$
   C. $n = 2$
   D. $n = 3$
   E. $n = \infty$

   ans: C

29. The most energetic photon in a continuous x-ray spectrum has an energy approximately equal to:
   A. the energy of all the electrons in a target atom
   B. the kinetic energy of an incident-beam electron
   C. the rest energy, mc^2, of an electron
   D. the total energy of a K-electron in the target atom
   E. the kinetic energy of a K-electron in the target atom

   ans: B

30. Two different electron beams are incident on two different targets and both produce x rays. The cutoff wavelength for target 1 is shorter than the cutoff wavelength for target 2. We can conclude that:
   A. target 2 has a higher atomic number than target 1
   B. target 2 has a lower atomic number than target 1
   C. the electrons in beam 1 have greater kinetic energy than those in beam 2
   D. the electrons in beam 1 have less kinetic energy than those in beam 2
   E. target 1 is thicker than target 2

   ans: C

31. A photon with the smallest wavelength in the continuous z-ray spectrum is emitted when:
A. an electron is knocked from a K shell
B. a valence electron is knocked from the atom
C. the incident electron becomes bound to the atom
D. the atom has the greatest recoil energy
E. the incident electron loses all its energy in a single decelerating event
ans: E

32. Radiation with the minimum wavelength as well as the K x-ray lines are detected for a certain target. The energy of the incident electrons is then doubled, with the result that
A. the minimum wavelength increases and the wavelengths of the K lines remain the same
B. the minimum wavelength decreases and the wavelengths of the K lines remain the same
C. the minimum wavelength and the wavelengths of the K lines all increase
D. the minimum wavelength and the wavelengths of the K lines all decrease
E. the minimum wavelength increases and the wavelengths of the K lines all decrease
ans: B

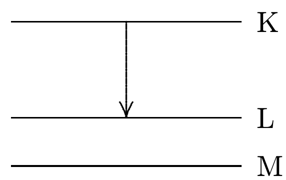
33. Characteristic K x-radiation of an element occurs when:
A. the incident electron is absorbed by a target nucleus
B. the incident electron is scattered by a target atom without an energy loss
C. an electron is ejected from an outer shell of a target atom
D. an electron in a target atom makes a transition to the lowest energy state
E. the incident electron goes into the lowest energy state
ans: D

34. The K_α x rays arising from a cobalt ($Z = 27$) target have a wavelength of about 179 pm. The atomic number of a target that gives rise to K_α x rays with a wavelength one-third as great (≈ 60 pm) is:
A. $Z = 9$
B. $Z = 10$
C. $Z = 12$
D. $Z = 16$
E. $Z = 46$
ans: E

35. In connection with x-ray emission the symbol K_α refers to:
A. an alpha particle radiation
B. an effect of the dielectric constant on energy levels
C. x-ray radiation from potassium
D. x-ray radiation associated with an electron going from $n = \infty$ to $n = 1$
E. x-ray radiation associated with an electron going from $n = 2$ to $n = 1$
ans: E

36. In connection with x-ray emission the symbol L_β refers to:
A. a beta particle radiation
B. an atomic state of angular momentum $h/2\pi$
C. the inductance associated with an orbiting electron
D. x-radiation associated with an electron going from $n = 4$ to $n = 2$
E. none of the above
ans: D

37. The transition shown gives rise to an x-ray. The correct label for this is:



A. K_α
B. K_β
C. L_α
D. L_β
E. KL
ans: A

38. In a Moseley graph:
A. the x-ray frequency is plotted as a function of atomic number
B. the square of the x-ray frequency is plotted as a function of atomic number
C. the square root of the x-ray frequency is plotted as a function of atomic number
D. the x-ray frequency is plotted as a function of the square root of atomic number
E. the square root of the x-ray frequency is plotted as a function of atomic mass
ans: C

39. In calculating the x-ray energy levels the effective charge of the nucleus is taken to be $Z - b$, where Z is the atomic number. The parameter b enters because:
A. an electron is removed from the inner shell
B. a proton is removed from the nucleus
C. the quantum mechanical force between two charges is less than the classical force
D. the nucleus is screened by electrons
E. the Pauli exclusion principle must be obeyed
ans: D

40. The ratio of the wavelength of the K_α x-ray line for Nb ($Z = 41$) to that of Ga ($Z = 31$) is:
A. 9/16
B. 16/9
C. 3/4
D. 4/3
E. 1.15
ans: A

41. The Pauli exclusion principle is obeyed by:

A. all particles
B. all charged particles
C. all particles with spin quantum numbers of 1/2
D. all particles with spin quantum numbers of 1
E. all particles with mass

ans: C

42. No state in an atom can be occupied by more than one electron. This is most closely related to:

A. the wave nature of matter
B. the finite value for the speed of light
C. the Bohr magneton
D. the Pauli exclusion principle
E. the Einstein-de Haas effect

ans: D

43. Electrons are in a two-dimensional square potential energy well with sides of length L. The potential energy is infinite at the sides and zero inside. The single-particle energies are given by $(h^2/8mL^2)(n_x^2 + n_y^2)$, where n_x and n_y are integers. At most the number of electrons that can have energy $8(h^2/8mL^2)$ is:

A. 1
B. 2
C. 3
D. 4
E. any number

ans: B

44. Five electrons are in a two-dimensional square potential energy well with sides of length L. The potential energy is infinite at the sides and zero inside. The single-particle energies are given by $(h^2/8mL^2)(n_x^2 + n_y^2)$, where n_x and n_y are integers. In units of $(h^2/8mL^2)$ the energy of the ground state of the system is:

A. 0
B. 10
C. 19
D. 24
E. 48

ans: C

45. Five electrons are in a two-dimensional square potential energy well with sides of length L. The potential energy is infinite at the sides and zero inside. The single-particle energies are given by $(h^2/8mL^2)(n_x^2 + n_y^2)$, where n_x and n_y are integers. In units of $(h^2/8mL^2)$ the energy of the first excited state of the system is:

A. 13
B. 22
C. 24
D. 25
E. 27

ans: B

46. Electrons are in a two-dimensional square potential energy well with sides of length L. The potential energy is infinite at the sides and zero inside. The single-particle energies are given by $(h^2/8mL^2)(n_x^2 + n_y^2)$, where n_x and n_y are integers. The number of single-particle states with energy $5(h^2/8mL^2)$ is:

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

ans: B

47. Six electrons are in a two-dimensional square potential energy well with sides of length L. The potential energy is infinite at the sides and zero inside. The single-particle energies are given by $(h^2/8mL^2)(n_x^2 + n_y^2)$, where n_x and n_y are integers. If a seventh electron is added to the system when it is in its ground state the least energy the additional electron can have is:

A. $2(h^2/8mL^2)$
B. $5(h^2/8mL^2)$
C. $10(h^2/8mL^2)$
D. $13(h^2/8mL^2)$
E. $18(h^2/8mL^2)$

ans: C

48. When a lithium atom is made from a helium atom by adding a proton (and neutron) to the nucleus and an electron outside, the electron goes into an $n = 2$, $\ell = 0$ state rather than an $n = 1$, $\ell = 0$ state. This is an indication that electrons:

A. obey the Pauli exclusion principle
B. obey the minimum energy principle
C. undergo the Zeeman effect
D. are diffracted
E. and protons are interchangeable

ans: A

49. When a lithium atom in its ground state is made from a helium atom by adding a proton (and neutron) to the nucleus and an electron outside, the electron goes into an $n = 2$, $\ell = 0$ state rather than an $n = 3$, $\ell = 0$ state. This is an indication that electrons:

A. obey the Pauli exclusion principle
B. obey the minimum energy principle
C. undergo the Zeeman effect
D. are diffracted
E. and protons are interchangeable

ans: B

50. If electrons did not have intrinsic angular momentum (spin) but still obeyed the Pauli exclusion principle, the states occupied by electrons in the ground state of helium would be:

A. $(n = 1, \ell = 0)$; $(n = 1, \ell = 0)$
B. $(n = 1, \ell = 0)$; $(n = 1, \ell = 1)$
C. $(n = 1, \ell = 0)$; $(n = 2, \ell = 0)$
D. $(n = 2, \ell = 0)$; $(n = 2, \ell = 1)$
E. $(n = 2, \ell = 1)$; $(n = 2, \ell = 1)$

ans: C

51. The minimum energy principle tells us that:

A. the energy of an atom with a high atomic number is less than the energy of an atom with a low atomic number
B. the energy of an atom with a low atomic number is less than the energy of an atom with a high atomic number
C. when an atom makes an upward transition the energy of the absorbed photon is the least possible
D. the ground state configuration of any atom is the one with the least energy
E. the ground state configuration of any atom is the one with the least ionization energy

ans: D

52. Which of the following (n, ℓ, m_ℓ, m_s) combinations is impossible for an electron in an atom?

A. 3, 1, 1, $-1/2$
B. 6, 2, 0, $1/2$
C. 3, 2, -2, $-1/2$
D. 3, 1, -2, $1/2$
E. 1, 0, 0, $-1/2$

ans: D

53. Which of the following subshells cannot exist?

A. 3p
B. 2p
C. 4d
D. 3d
E. 2d

ans: E

54. For any atom other than hydrogen and helium all electrons in the same shell have:
 A. the same energy
 B. the same magnitude of angular momentum
 C. the same magnetic quantum number
 D. the same spin quantum number
 E. none of the above
 ans: E

55. The states being filled from the beginning to end of the lanthanide series of atoms are:
 A. $n = 3$, $\ell = 2$ states
 B. $n = 4$, $\ell = 1$ states
 C. $n = 4$, $\ell = 2$ states
 D. $n = 4$, $\ell = 3$ states
 E. $n = 5$, $\ell = 2$ states
 ans: D

56. The most energetic electron in any atom at the beginning of a period of the periodic table is in:
 A. an $\ell = 0$ state
 B. an $\ell = 1$ state
 C. an $\ell = 2$ state
 D. an $n = 0$ state with unspecified angular momentum
 E. an $n = 1$ state with unspecified angular momentum
 ans: A

57. The most energetic electron in any atom at the end of a period of the periodic table is in:
 A. an $\ell = 0$ state
 B. an $\ell = 1$ state
 C. an $\ell = 2$ state
 D. an $n = 0$ state with unspecified angular momentum
 E. an $n = 1$ state with unspecified angular momentum
 ans: B

58. The group of atoms at the ends of periods of the periodic table are called:
 A. alkali metals
 B. rare earths
 C. transition metal atoms
 D. alkaline atoms
 E. inert gas atoms
 ans: E

59. The group of atoms at the beginning of periods of the periodic table are called:

A. alkali metal atoms
B. rare earth atoms
C. transition metal atoms
D. alkaline atoms
E. inert gas atoms

ans: A

60. Suppose the energy required to ionize an argon atom is i, the energy to excite it is e, and its thermal energy at room temperature is t. In increasing order, these three energies are:

A. i, e, t
B. t, i, e
C. e, t, i
D. i, t, e
E. t, e, i

ans: C

61. The ionization energy of an atom in its ground state is:

A. the energy required to remove the least energetic electron
B. the energy required to remove the most energetic electron
C. the energy difference between the most energetic electron and the least energetic electron
D. the same as the energy of a K_α photon
E. the same as the excitation energy of the most energetic electron

ans: B

62. The effective charge acting on a single valence electron outside a closed shell is about Ne, where N is:

A. the atomic number of the nucleus
B. the atomic mass of the atom
C. usually between 1 and 3
D. half the atomic number
E. less than 1

ans: C

63. In a laser:

A. excited atoms are stimulated to emit photons by radiation external to the laser
B. the transitions for laser emission are directly to the ground state
C. the states which give rise to laser emission are usually very unstable states that decay rapidly
D. the state in which an atom is initially excited is never between two states that are involved in the stimulated emission
E. a minimum of two energy levels are required.

ans: D

64. Photons in a laser beam have the same energy, wavelength, polarization direction, and phase because:

A. each is produced in an emission that is stimulated by another
B. all come from the same atom
C. the lasing material has only two quantum states
D. all photons are alike, no matter what their source
E. none of the above

ans: A

65. A laser must be pumped to achieve:

A. a metastable state
B. fast response
C. stimulated emission
D. population inversion
E. the same wavelength for all photons

ans: D

66. Photons in a laser beam are produced by:

A. transitions from a metastable state
B. transitions to a metastable state
C. transitions from a state that decays rapidly
D. splitting of other photons
E. pumping

ans: A

67. Which of the following is essential for laser action to occur between two energy levels of an atom?

A. the lower level is metastable
B. the upper level is metastable
C. the lower level is the ground state
D. there are more atoms in the lower level than in the upper level
E. the lasing material is a gas

ans: B

68. Which of the following is essential for laser action to occur between two energy levels of an atom?

A. the lower level is metastable
B. there are more atoms the upper level than in the lower level
C. there are more atoms in the lower level than in the upper level
D. the lower level is the ground state
E. the lasing material is a gas

ans: B

69. Population inversion is important for the generation of a laser beam because it assures that:

A. spontaneous emission does not occur more often than stimulated emission
B. photons do not split too rapidly
C. more photons are emitted than are absorbed
D. photons do not collide with each other
E. photons do not make upward transitions

ans: C

70. A metastable state is important for the generation of a laser beam because it assures that:

A. spontaneous emission does not occur more often than stimulated emission
B. photons do not split too rapidly
C. more photons are emitted than are absorbed
D. photons do not collide with each other
E. photons do not make upward transitions

ans: A

71. Electrons in a certain laser make transitions from a metastable state to the ground state. Initially there are 6×10^{20} atoms in the metastable state and 2×10^{20} atoms in the ground state. The number of photons that can be produced in a single burst is about:

A. 2×10^{20}
B. 3×10^{20}
C. 4×10^{20}
D. 6×10^{20}
E. 8×10^{20}

ans: C

72. In a helium-neon laser, the laser light arises from a transition from a ______ state to a ______ state.

A. He, He
B. Ne, Ne
C. He, Ne
D. Ne, He
E. N, He

ans: B

73. The purpose of the mirrors at the ends of a helium-neon laser is:

A. to assure that no laser light leaks out
B. to increase the number of stimulated emissions
C. to absorb some of the photons
D. to keep the light used for pumping inside the laser
E. to double the effective length of the laser

ans: B

74. A group of electromagnetic waves might

I. be monochromatic
II. be coherent
III. have the same polarization direction

Which of these describe the waves from a laser?

A. I only
B. II only
C. III only
D. I and II only
E. I, II, and III

ans: E

75. A laser beam can be sharply focused because it is:

A. highly coherent
B. plane polarized
C. intense
D. circularly polarized
E. highly directional

ans: E

76. The "e" in laser stands for:

A. electric
B. emf
C. energy
D. emission
E. entropy

ans: D