PHYSICS

BOOKS - RESNICK AND HALLIDAY PHYSICS (HINGLISH)

ALL ABOUT ATOMS

Sample Problem

1. A beam of 35.0 keV electrons strikes a molybdenum target, generating the x rays whose spectrum is shown in Fig. What is the cutoff wavelength?

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2. A cobalt target $(Z = 27)$ is bomberded with electron and the wavelength of its characteristic spectrum are measured . A second , fainter characcteristic spectrum is also found because of an impurity in the target. The wevelength of the K_{α} lines are

178.9 pm (cobalt) and $143.5 \pm$ (impurity).

What is the impurity?

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3. In the helium-neon laser of laser action occurs between two excited states of the neon atom. However, in many lasers, laser action (lasing) occurs between the ground state and an excited state, as suggested in fig.

(a) Consider such a laser that emits at wavelength $\lambda = 550 nm$. If a population inversion is not generated what is the ratio of the population of atoms in state E_x to the population in the ground state E_0, with the atoms at room temperature?

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Problems

1. Show that the number of states with the same quantum number n is $2n^2$.

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2. A hypothetical atom has only two atomic energy levels, separated by 3.2 eV. Suppose that at a certain altitude in the atmosphere of a star there are $6.1 \times 10^{13} / cm^3$ of these atoms in the higher-energy state and are $2.2 \times 10^{15} / cm^3$ in the lower-energy state. What is the temperature of the star's atmosphere at that altitude?

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3. Suppose two electrons in an atom have quantum numbers $n = 2$ and $l = 1$. (a) How many states are possible for those two electrons? (Keep in mind that the electrons are indistinguishable). (b) If the Pauli exclusion principle did not apply to the electrons, how many states would be possible?

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4. An electron in a mercury atoms is in the 3d subshell. Which of the following m_l values are possible for it, (a) -3, (b) -1, (c) 0, (d) 1, (e) 2?

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5. An atom of uranium has closed 6p and 7s subshell. Which subshell has greater number of electrons?

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6. A tungsten $(Z = 74)$ target is bombarded by electrons in an x-ray tube. The K, L and M energy levels for tungsten have the energies 69.5, 11.3, and 2.30 ke V, respectively. (a) What is the minimum value of the accelerating potential that will permit the production of the characteristic K_α and K_β lines of tungsten? (b) For this same accelerating potential, what is $\lambda_{\min}$? What are the (c) K_α and (d) K_{bet} wavelengths?

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7. A high-powered laser beam $(\lambda = 600 nm)$ with a beam diameter of 10 cm is aimed at the Moon, $3.8 \times 10^5 km$ distant. The beam spreads only because of diffraction. The angular location of the edge of the central diffraction disk is given by

$$\sin\theta = \frac{1.22\lambda}{d},$$

where d is the diameter of the beam aperture. What is the diameter of the central diffraction disk on the Moon's surface?

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8. What are the initial and final shells for an M_β line in an x-ray spectrum?

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9. Consider the elements selenium $(Z = 34)$, bromine $(Z = 35)$, and krypton $(Z = 36)$. In their part of the periodic table, the subshells of the electronic states are filled in the sequence.

$1s2s2p3s3p3d4s4p\ldots\ldots$

What are (a) the highest occupied subshell for selenium and (b) the number of electrons in it, (c) the highest occupied subshell for bromine and (d) the number of electrons in it, and (e) the highest occupied subshell for krypton and (f) the number of electrons in it?

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10. Which element has K_{α} x-ray line whose wavelength is 0.180 nm?

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11. An X-ray tube operates at 20 kV. A particular electron loses 5% of its kinetic energy to emit an X-ray photon at the first collision. Find the wavelength corresponding to this photon.

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12. The x rays shown are produced when 35.0 ke V electrons strike a molybdenum $(Z = 42)$ target. If the accelerating potential is maintained at this value but a silver $(Z = 47)$

target is used instead, what values of (a) $\lambda_{\min}$, (b) the wavelength of the K_α line, and (c) the wavelength of the K_β line result? The K, L, and M atomic x-ray levels for silver are 25.51, 3.56, and 0.53 keV.

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13. (a) From Eq. what is the ratio of the photon energies due to K_α transitions in two atoms whose atomic numbers and Z and Z? (b) What is this ratio for uranium and aluminum? (c) For uranium and lithium?

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14. Show that a moving electron cannot spontaneously change into an x-ray photon in free space. A third body (atom or nucleus) must be present. Why is it needed?

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15. A population inversion for two energy levels is often described by assigning a negative Kelvin temperature to the system. What negative temperature would describe a system in which the population of the upper energy level exceeds that of the lower level by 10% and the energy difference between the two levels is 2.32 eV?

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16. Two of the three electrons in a lithium atom have quantum numbers (n, l, m_l, m_s) of $(1, 0, 0, +1/2)$ and $(1, 0, 0, -1/2)$. What quantum numbers are possible for the third electron if the atom is (a) in the ground state and (b) in the first excited state?

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17. A pulsed laser emits light at a wavelength of 694.4 nm. The pulse duration is 12 ps, and the energy per pulse is 0.150 J. (a) What is the length of the pulse? (b) How many photons are emitted in each pulse?

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18. From Fig, calculate approximately the energy different $E_L - E_M$ for molybdenum. Compare it with the value that may be obtained from Fig.

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19. For a helium atom in its ground state, what are quantum numbers $(n, l, m_l \text{ and } m_s)$ for the (a) spin-up electron and (b) spin-down electron?

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20. A hypothetical atom has two energy levels, with a transition wavelength between them of 580 nm. In a particular sample at 300 K, 4.0×10^{20} such atoms are in the state of lower energy. (a) How many atoms are in the upper state, assuming conditions of thermal equilibrium? (b) Suppose, instead, that 3.0×10^{20} of these atoms are "pumped" into the upper state by an external process, with 1.0×10^{20} atoms remaining in the lower state.

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21. A laser emits at 424 nm in a single pulse that lasts $0.500 \mu s$. The power of the pulse is 3.25 MW. If we assume that the atoms contributing to the pulse underwent stimulated emission only once during the $0.500 \mu s$, how many atoms contributed?

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22. X rays are produced in an x-ray tube by electrons accelerated through an electric potential difference of 50.0 kV. Let K_0 be the kinetic energy of an electron at the end of the acceleration. The electron collides with a target nucleus (assume the nucleus remains stationary) and then has kinetic energy

$K_1 = 0.500K_0$. (a) What wavelength is associated with the photon that is emitted? The electron collides with another target nucleus (assume it, too, remain stationary) and then has kinetic energy $K_2 = 0.500K_1$. (b) What wavelength is associated with the photon that is emitted?

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23. Assume that lasers are available whose wavelengths can be precisely "tuned" to anywhere in the visible range-that is, in the range $450nm < \lambda < 650nm$. If every television channel occupies a bandwidth of 10 MHz, how many channels can be accommodated within this wavelength range?

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24. A certain gas laser can emit light at wavelength 550 nm, which involves population inversion between ground state and an excited state. At room temperature, how many moles of neon are needed to put 12 atoms in that excited state by thermal agitation?

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25. How many electron states are there in the following shells:

(a) $n = 4$, (b) $n = 1$, (c) $n = 3$, (d) $n = 2$?

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26. The active volume of a laser constructed of the semiconductor GaAIAs is only $200\mu m^3$ (smaller than a grain of sand), and yet the laser can continuously deliver 5.0 mW of power at a wavelength of $0.80\mu m$. At what rate does it generate photons?

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27. In the subshell $l = 4$, (a) what is the greatest (most positive) m_l value, (b) how many states are available with the greatest m_f value, and (c) what is the total number of states available in the subshell?

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28. A material whose K -absorption edge is 0.2Å is irradiated by X-ray of wavelength 3644Å , find the maximum energy of the photoelectrons that are emitted from the K shell.

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29. The wavelength of the K_α line from iron is 193 pm. What is the energy difference between the two states of the iron atom that give rise to this transition?

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30. An electron in a multielectron atom has $m_f = +4$. For this electron, what are (a) the value of l, (b) the smallest possible value of n, and (c) the number of possible values of m_s?

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31. A hypothetical atom has energy levels uniformly separated by 1.2 eV. At a temperature of 2000 K, what is the ratio of the number of atoms in the 13th excited state to the number in the 11th excited state?

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32. Ruby lases at a wavelength of 694 nm. A certain ruby crystal has $4.00 \times 10^{19} Cr$ ions (which are the atoms that lase). The lasing transition is between the first excited state and the ground state, and the output is a light pulse lasting $1.50 \mu s$. As the pulse begins, 60.0% of the Cr ions are in the first excited state and the rest are in the ground state. What is the average power emitted during the pulse?

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33. How many electron states are there in a shell defined by the quantum number $n = 6$?

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34. Through what minimum potential difference must an electron in an x-ray tube be accelerated so that it can produce x rays with a wavelength of 0.100 nm?

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35. Calculate the ratio of the wavelength of the K_{α} line for niobium (Nb) to that for gallium (Ga). Take needed data from the periodic table of Appendix G.

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36. An electron is in a state with $l = 3$, (a) What multiple of h gives the magnitude of $\overrightarrow{L}$? (b) What multiple of μ_B gives the magnitude of $\overrightarrow{\mu}$? (c) What is the largest possible value of m_l? (d) what multiple of h gives the corresponding value of L_z, and (e) what multiple of μ_B gives the corresponding value of $\mu_{\text{ or } b,z}$? (f) What is the value of the semiclassical angle θ between the direction of L_z and $\overrightarrow{L}$? What is the value of angle θ for (g) the second largest possible value of m_l and (h) the smallest (that is, most negative) possible value of m_l?

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37. When electrons bombard a molybdenum target, they produce both continuous and characteristic x rays as shown in fig. In that figure the kinetic energy of the incident electrons is 35.0 keV, (a) what is the value of $\lambda_{\min}$, and (b) do the wavelengths of the K_α and K_β lines increase, decrease, or remain the same?

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38. An electron in a hydrogen atom is in a state with $l = 5$. What is the minimum possible value of the semiclassical angle between $\vec{L}$ and L_z?

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39. An electron is in a state with n=4. What are (a) the number of possible values of l, (b) the number of possible values of m_l, (c) the number of poosible values of m_s, (d) the number of states in the $n = 4$ shell, and (e) the number of subshells in the $n = 4$ shell?

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40. (a) How many l values are associated with $n = 3$? (b) How many m_l, values are associated with $l = 1$?

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41. The active medium in a particular laser that generates laser light at a wavelength of 694 nm is 6.00 cm long and 1.00 cm in diameter. (a) Treat the medium as an optical resonance cavity analogous to a closed organ pipe. How many standingwave nodes are there along the laser axis? (b) By what amount Δf would the beam frequency have to shift to increase of the travel by one? (c) Show that Δf is just the inverse of the travel time of laser light for one round trip back and forth along the laser axis. (d) What is the corresponding fractional frequency shift $\Delta f / f$? The appropriate index of refraction of the lasing medium (a ruby crystal) is 1.75.

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42. How many electron states are in these subshells: (a) $n = 4, l = 3$, (b) $n = 3, l = 2$, (c) $n = 4, l = 1$, (d) $n = 2, l = 0$?

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43. (a) What is the magnitude of the orbital angular momentum in a state with $l = 3$? (b) What is the magnitude of its largest projection on an imposed z axis?

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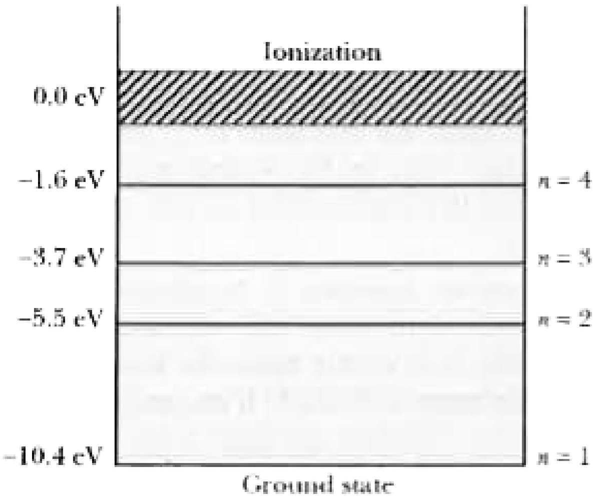
44. Fig shows that energy levels of a mercury atom. Electrons with kinetic energies of 7.0 eV are introduced into mercury vapor. (a) Convert the energy levels to the system that sets the ground state at 0 eV. (b) What is the kinetic energy of an electron after an elastic collision with a mercury atom? (c) What are the possible kinetic energies of an electron after an inelastic collision with a mercury atom? (d) What are the energies of the photons coming from the mercury vapor?



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45. The k_{α} X-rays of aluminium (Z = 13) and zinc (Z = 30) have wavelengths 887 pm and 146 pm respectively. Use Moseley\'s law $\sqrt{v} = a(Z - b)$ to find the wavelength of the K_{α} X-ray of iron (Z = 26).

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46. An imaginaryy atom whose energy levels are shown here undergoes an Auger

transition. This implies that the x-ray photon emitted during transition from L to K state is absorbed by another electron in M shell and it comes out of the atom. Calculate the initial energy of the Auger electron as in fig.

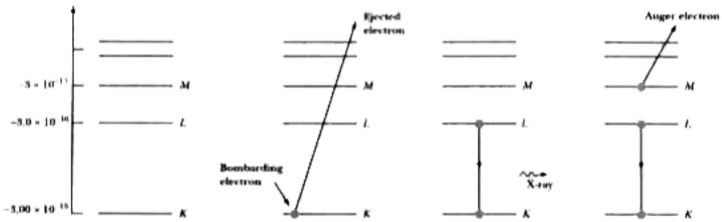

Figure 39-21 Problem 50.

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47. (a) Find the energy in electron volts required to strip a calcium atom $(Z = 20)$ of its last electron, assuming the other 19 have been removed. How does this compare with the energy required to excite the K_{α} x-ray lines of Ca, which is about 3.7 keV? (b) Why there is a difference?

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48. The Ka X-ray of molybdenum has wavelength 71 pm. If the energy of a molybdenum atom with a K electron knocked out is 23:32 keV, what will be the energy of this atom when an L electron is knocked out?

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Practice Questions Single Correct Choice Type

1. Electrons with energy $80keV$ are incident on the tungsten target of an X - rays tube , k-shell electrons of tungsten have $72.5keV$ energy X- rays emitted by the tube contain only

A. A continuous x-ray spectrum (Bremsstrahlung) with a minimum wavelength of ~$0.155 Å$

B. A continuous x-ray spectrum (Bremsstrahlung) with all wavelengths

C. The characteristic x-ray spectrum of tungsten

D. A continuous x-ray spectrum (Bremsstrahlung) with a minimum wavelength of ~$0.155 Å$ and the characteristic x-ray spectrum of tungsten

Answer: C

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2. If the atom$(_100)Fm^{257}$ follows the Bohr model the radius of $\_(100)Fm^{257}$ is n time the Bohr radius , then find n .

A. $1/4$

B. 4

C. 50

D. 100

Answer: A

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3. An element of atomic number 9 emits K_α X-ray of wavelength λ. Find the atomic number of the element which emits K_α X-ray of wavelength 4λ.

A. 4

B. 5

C. 6

D. 7

Answer: B

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4. Electrons with de-Broglie wavelength λ fall on the target in an X-ray tube. The cut-off wavelength of the emitted X-ray is

A. $\lambda_0 = \frac{2mc\lambda^2}{h}$

B. $\lambda_0 = \frac{2h}{mc}$

C. $\lambda_0 = \frac{2m^2c^2\lambda^3}{h^2}$

D. $\lambda_0 = \lambda$

Answer: A

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5. Which one of the following statement is $WRONG$ in the context of X- rays generated from X- rays tube ?

A. Wavelength of characteristic x-rays decreases when the atomic number of the target increases

B. Cut-off wavelength of the continuous x-rays depends on the atomic number of the target

C. Intensity of the characteristic x-rays depends on the electrical power given to the x-ray tube

D. Cut-off wavelength of the continuous x-rays depends on the energy of the electrons in the x-ray tube

Answer: B

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6. If λ_{Cu} is the wavelength of K_{α} X-ray line of copper (atomic number 29) and λ_{Mo} is the wavelength of the K_{α}X-ray line of molybdenum (atomic number 42),then the ratio $\lambda_{Cu} / \lambda_{Mo}$ is close to

A. 1.99

B. 2.14

C. 0.50

D. 0.48

Answer: B

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7. A diatomic molecule is made of two masses m_1 and m_2 which are separated by a distance r . If we calculate its rotational energy by applying Bohr's rule of angular momentum quantization it energy will be (n is an integer)

A. $\frac{(m_1+m_2)^2 n^2 h^2}{2 m_1^2 m_2^2 r^2}$

B. $\frac{n^2 h^2}{2(m_1+m_2) r^2}$

C. $\frac{2 n^2 h^2}{(m_1+m_2) r^2}$

D. $\frac{(m_1+m_2) n^2 h^2}{2 m_1 m_2 r^2}$

Answer: D

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8. An atom stays in an excited state for about

A. $10\mu s$

B. $10ms$

C. $10ns$

D. $10s$

Answer: C

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9. The ratio of magnetic field at the center due to the rotation of a Bohr's electron in the first state of hydrogen atom and second excited state of Li^{++} atom is

A. $9:1$

B. $27:4$

C. $9:4$

D. $27:1$

Answer: A

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10. With increasing quantum numbers, the energy difference between adjacent energy level atoms

A. Increases

B. Decreases

C. Remains constant

D. First increases then decreases

Answer: B

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11. If in nature they may not be an element for which the principle quantum number $n > 4$, then the total possible number of elements will be

A. 60

B. 32

C. 4

D. 64

Answer: A

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12. An electron has a mass of $9.1 \times 10^{-31} kg$. It revolves round the nucleus in a circular orbit of radius 0.529×10^{-10} metre at a speed of $2.2 \times 10^{6} m/s$. The magnitude of its linear momentum in this motion is

A. $1.1 \times 10^{-34} kg.m/s$

B. $2.0 \times 10^{-24} kg.m/s$

C. $4.0 \times 10^{-24} kg. m / s$

D. $4.0 \times 10^{-31} kg. m / s$

Answer: B

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13. In a beryllium atom, if a_0 be the radius of the first orbit, then the radius of the second orbit will be in general

A. na_0

B. a_0

C. $n^2 a_0$

D. $\frac{a_0}{n^2}$

Answer: C

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14. The velocity of an electron in its fifth orbit, if the velocity of an electron in the second orbit of sodium atom (atomic number =11) is v, will be :

A. v

B. $\frac{22}{5}v$

C. $\frac{5}{2}v$

D. $\frac{2}{5}v$

Answer: D

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15. The number of values of the orbital quantum number associated with the principal quantum number $n = 3$ is

A. 1

B. 2

C. 9

D. 4

Answer: C

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16. The number of states in a shell with principal quantum number $n = 3$ is

A. 3

B. 9

C. 15

D. 18

Answer: D

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17. Of the following states, $5s$, $3p$, $4f$, $5p$, $4g$, $3d$, and $2p$, the one which is NOT allowed is

A. 3p

B. 4f

C. 3d

D. 4g

Answer: D

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18. An electron is in a quantum state for which the magnitude of the orbital angular momentum is $6\sqrt{2}h/2\pi$. How many allowed values of the z component of the angular momentum are there?

A. 4

B. 5

C. 7

D. 8

Answer: D

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19. An electron in an atom is in a state with $l = 1$. The minimum angle (in degree) between $\vec{L}$ and the z axis is

A. 0

B. 18.0

C. 45

D. 36.7

Answer: A

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20. The spin angular momentum of an electron is equal to

A. $\sqrt{3}$

B. $h\sqrt{3}/4\pi$

C. $h/2$

D. $\pm h/2$

Answer: B

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21. The X-ray beam coming from an X-ray tube

A. Is monochromatic

B. Has all wavelengths smaller than a certain maximum wavelength

C. Has all wavelengths greater than a certain minimum wavelength

D. Has all wavelengths lying between a minimum and a maximum wavelength

Answer: C

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22. The mimmum wevelength of X-ray that can be produced in a Coolisge tube depends on

A. The metal used as the target

B. The intensity of the electron beam striking the target

C. The current flowing through the filament

D. The potential difference between the cathode and the anode

Answer: D

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23. If the potential difference applied to tube is doubled and the separation between the filament and the target is also doubled, the cutoff wavelength

A. Will remain unchanged

B. Will be doubled

C. Will be halved

D. Will become four times the original

Answer: C

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24. If the current in the circuit for heating the filament is increased, the cutoff wavelength

A. Will increase

B. Will decrease

C. Will remain unchanged

D. Will change

Answer: C

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25. If a potential difference of 20,000 volts is applied across X-ray tube , the cut -off wavelength will be

A. $6.21 \times 10^{-10} m$

B. $6.21 \times 10^{-11} m$

C. $6.21 \times 10^{-12} m$

D. $3.1 \times 10^{-11} m$

Answer: B

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26. The potential difference applied to an X-ray tube is 5k V and the current through it is 3.2 mA. Then, the number of electrons striking the target per second is. (a) 2×10^{16} (b) 5×10^{6} (c) 1×10^{17} (d) 4×10^{15}.

A. 2×10^{16}

B. 5×10^{6}

C. 1×10^{17}

D. 4×10^{15}

Answer: A

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27. In an x-ray tube, the target should be made up of material having

A. High atomic number and low thermal conductivity

B. High atomic number and high thermal conductivity

C. Low atomic number and low thermal conductivity

D. Low atomic number and high thermal conductivity

Answer: B

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28. X ray can be made harder by

A. Increasing the potential difference between cathode and target

B. Decreasing the potential difference between cathode and target

C. Increasing the current through filament

D. Decreasing the current through filament

Answer: A

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29. Which of the following wavelength falls in X - ray region

A. 10000Å

B. 1000Å

C. 1Å

D. 10^{-2}Å

Answer: C

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30. The energy of a photon of characteristic X-ray from a Coolidge tube comes from

A. The kinetic energy of the striking electron

B. The kinetic energy of the electrons of the target

C. The kinetic energy of the ions of the target

D. An atomic transition in the target

Answer: D

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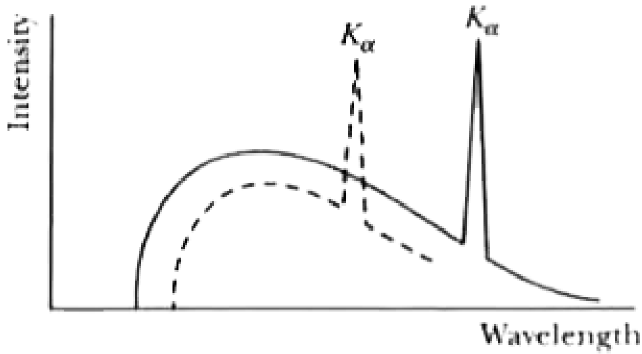
31. The following figure shows the intensity-wavelength relations of x-rays coming from two different Coolidge tubes. The solid curve represents the relation for tube A in which the potential difference between the target and the filament is V_A and the atomic number of the target material is Z_A. These quantities are

V_B and Z_B for the other tube. Then



A. $V_A > V_B, V_A > Z_B$

B. $V_A > V_B, Z_A < Z_B$

C. $V_A < V_B, Z_A > Z_B$

D. $V_A < V_B, Z_A < Z_B$

Answer: B

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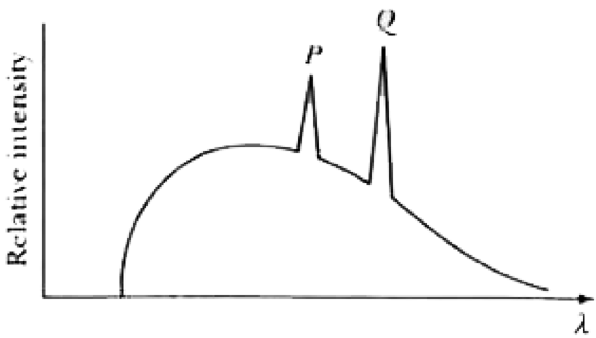
32. In a characteristic x-ray spectra (as shown in the following figure), L shell of some element is superimposed on continuous x-ray spectra. Ere



A. P can represent L_{α} line

B. Q represents L_{α} line

C. Q and P represent L_α and L_β lines, respectively

D. Q and P represent L_β and L_α lines, respectively

Answer: C

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33. The $K_\alpha X$-ray emission line of tungsten occurs at $\lambda = 0.021 nm$. The energy difference between K and L levels in this aotm is about :

$0.51 MeV$

A. 0.51 MeV

B. 1.2 MeV

C. 59 ke V

D. 13.6 eV

Answer: C

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34. Mosley's law for characteristic x rays is given by $\sqrt{f} = a(Z - b)$

Choose the correct statement(s).

A. Both a and b depend on the target material

B. Both a and b are independent of the target material

C. Both a and b depend on the energy of the electron beam

D. Both a and b depend on the nature of the lines (i.e.,K,L,M,...)

Answer: D

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35. The wavelength of the K_{α} line for an element of atomic number 57 is λ . What is the wavelength of the K_{α} line for the element of atomic number29 ?

A. α

B. 2α

C. 4α

D. 8α

Answer: C

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36. If the frequency of K_{α}, K_{β} and L_{α} , X-ray lines of a substance are $v_{K_{\alpha}}, v_{K_{\beta}}$, and $v_{L_{\beta}}$

A. $v_{K_\alpha} = v_{K_\beta} + v_{L_\alpha}$

B. $v_{L_\alpha} = v_{K_\alpha} + v_{K_\beta}$

C. $v_{K_\beta} = v_{K_\alpha} + v_{L_\alpha}$

D. None of these

Answer: C

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37. The K, L, and M energy levels of platinum lie roughly at 78, 12, and 3 KeV, respectively. The ratio of wavelength of K_α line to that of K_β

line in x-ray spectrum is

A. $\frac{22}{3}$

B. $\frac{3}{22}$

C. $\frac{22}{25}$

D. $\frac{25}{22}$

Answer: D

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38. The potential difference applied to an X-ray tube is V The ratio of the de Broglie wavelength of electron to the minimum wavlength of X-ray is directrly proportional to

A. V

B. $V^{1/2}$

C. $1/\sqrt{V}$

D. Independent of V

Answer: B

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39. The energy of a tungsten atom with a vacancy in L small is $11.3KaV$. Wavelength of K_{α} photon for tungsten is 21.3pm. If a potential difference of $62kV$ is applied across the X-raystube following characterstic X-rays will be produced.

A. K, L series

B. Only K_{α} and L series

C. Only L series

D. None

Answer: B

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40. 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

Answer: A

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41. Photons in a laser beam are produced by

A. Transition from a metastable state

B. Transitions to a metastable state

C. Transitions from a state that decays rapidly

D. Pumping

Answer: A

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42. 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. More photons are emitted than are absorbed

C. Photons do not collide with each other

D. Photons do not make upward transitions

Answer: A

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43. Each atom in the periodic table has a unique set of spectral lines. Which one of the following statements is the best explanation for this observation?

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44. Which one of the following pairs of characteristics of light is best explained by assuming that light can be described in terms of photons?

A. Photoelectric effect and the effect observed in Young's experiment

B. Diffraction and the formation of atomic spectra

C. Polarization and the photoelectric effect

D. Existence of line spectra and the photoelectric effect

Answer: D

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45. Complete the following statement: An individual copper atom emits electromagnetic radiation with wavelengths that are

A. Evenly spaced across the spectrum

B. Unique to that particular copper atom

C. The same as other elements in the same column of the periodic table

D. Unique to all copper atoms

Answer: D

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46. Determine the maximum wavelength of incident radiation that can be used to remove tha remaining electron from a singly ionized helium atom $He^+(Z = 2)$. Assume the electron is in its ground state

A. 6.2 nm

B. 22.8 nm

C. 12.4 nm

D. 45.6 nm

Answer: B

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47. To which model of atomic structure does the Pauli exclusion principle apply?

A. The nuclear atom

B. The quantum mechanical atom

C. The billiard ball atom

D. The plum-pudding model

Answer: B

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48. Which one of the following statements concerning the electrons specified by the notation $3p^4$ is true?

A. The electrons are in the M shell

B. The electrons are in the $l = 2$ subshell

C. The electrons are necessarily in an excited state

D. They have principal quantum number 4

Answer: A

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49. Which one of the following subshells is not compatible with a principal quantum number of $n = 4$?

A. s

B. d

C. g

D. p

Answer: C

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50. Which one of the following electronic configurations corresponds to an atomic ground state?

A. $1s^2 2s^1 2p^6$

B. $1s^1 2s^2 3p^1$

C. $1s^1 2s^1 2p^1$

D. $1s^2 2s^2 2p^1$

Answer: D

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51. In an x-ray tube, electrons with energy 35 keV are incident on a cobalt $(Z = 27)$ target. Determine the cutoff wavelength for x-ray production.

A. $1.4 \times 10^{-11} m$

B. $3.6 \times 10^{-11} m$

C. $1.8 \times 10^{-11} m$

D. $3.2 \times 10^{-11} m$

Answer: B

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52. Which one of the following statements concerning the cutoff wavelength typically exhibited in x-ray spectra is true?

A. The cutoff wavelength depends on the target material

B. The cutoff wavelength depends on the potential difference across the x-ray tube

C. The cutoff wavelength is independent of the energy of the incident electrons

D. The cutoff wavelength occurs because of the mutual shielding effects of K-shell electrons

Answer: B

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53. Calculate the K_{α} x-ray wavelength for a gold atom $(Z = 79)$.

A. $5.13 \times 10^{-10} m$

B. $2.00 \times 10^{-11} m$

C. $8.54 \times 10^{-10} m$

D. $3.60 \times 10^{-11} m$

Answer: B

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54. Electrons in an x-ray tube are accelerated through a potential $(Z = 40)$ target. Determine the cutoff frequency for x-ray production.

A. $4.7 \times 10^{19} Hz$

B. $3.2 \times 10^{18} Hz$

C. $9.7 \times 10^{18} Hz$

D. $6.7 \times 10^{17} Hz$

Answer: C

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55. What is the operating voltage of a medical x-ray machine that has a cut-off wavelength of $2.20 \times 10^{-11} m$?

A. 83 800 V

B. 56 500 V

C. 10 900 V

D. 44 900 V

Answer: B

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56. An argon-ion laser emits a blue-green beam of light with a wavelength of 488 nm in a vacuum. What is the difference in energy in joules between the two energy states for the atomic transition that produces this light?

A. $4.08 \times 10^{-19} J$

B. $6.18 \times 10^{-20} J$

C. $1.05 \times 10^{-20} J$

D. $4.76 \times 10^{-24} J$

Answer: A

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57. A pulsed laser has an average output power of 4.0 W. Each pulse consists of light at wavelength $5.0 \times 10^{-7} m$ and has a 25 ms duration. How many photons are emitted in a single pulse?

A. 1.0×10^{17}

B. 3.7×10^{17}

C. 2.5×10^{17}

D. 5.0×10^{17}

Answer: C

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Practice Questions More Than One Correct Choice Type

1. A single electron orbits around a stationary nucleus of charge $+Ze$ where Z is a constant and e is the magnitude of electronic charge. It requires 47.2 eV to excite the electron from the second bohr orbit to the third bohr orbit

a. Find the value of Z

b. Find the energy required to excite the electron from $n = 3 \text{ to } n = 4$

c. Find the wavelength of radiation required to remove the electron from the second bohr orbit to infinity

d. Find the kinetic energy, potential energy and angular momentum of the electron in the first orbit

e. Find the ionisation energy of above electron system in electron-volt.

A. The value of Z is 5

B. The wavelength of electromagnetic radiation required to remove the electron from first orbit to infinity is nearly 3653 pm

C. The radius of the first orbit is 10.6 pm

D. The angular momentum of the electron in first orbit is $1.05 \times 10^{-34} J.s$

Answer: A::B::C::D

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2. A X-ray tube operates at an accelerating potntial of 20 kV. Which of the following wavelength will be absent in the continuous spectrum of X-rays ?

A. $12 \pm$

B. $45 \pm$

C. $65 \pm$

D. $95 \pm$

Answer: A::B

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3. Electrons with energy $80keV$ are incident on the tungsten target of an X - rays tube , k-shell electrons of tungsten have $72.5keV$ energy X- rays emitted by the tube contain only

A. A continuous x-ray spectrum (Bremsstrahlung) with a minimum wavelength of $0.155 \mathring{A}$

B. A continuous x-ray spectrum (Bremsstrahlung) with all wavelengths

C. The characteristic x-ray spectrum of tungsten

D. A continuous x-ray spectrum (Bremsstrahlung) with a minimum wavelength of $0.155 \mathring{A}$ and the characteristic x-ray spectrum of tungsten

Answer: A::C::D

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4. Which (if any) of the following are essential for laser action to occur between two energy levels of an atom?

A. There are more atoms in the upper level than in the lower

B. The upper level is metastable

C. The lower level is metastable

D. The lower level is the ground state of the atom

Answer: A::B

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Practice Questions Comprehension

1. When a particle is restricted to move along x-axis between $x = 0$ and $x = a$, where α if of nenometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is related to the linear momentum p of the particle according to the de Broglie relation.

The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$. Thus the energy of the particle can be denoted by a quantum number n taking values 1,2,3, ...($n = 1$, called the ground state) corresponding to the number of loops in the standing wave.

Use the model described above to answer the following three questions for a particle moving along the line from $x = 0$ to $x = \alpha$. Take $h = 6.6 \times 10^{-34} Js$ and $e = 1.6 \times 10^{-19}$ C.

Q. The allowed energy for the particle for a particular value of n is proportional to

A. a^{-2}

B. $a^{-3/2}$

C. a^{-1}

D. a^{2}

Answer: A

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2. When a particle is restricted to move along x-axis between $x = 0$ and $x = a$, where α if of nenometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is related to the linear momentum p of the particle according to the de Broglie relation. The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$. Thus the energy of the particle can be denoted by a quantum number n taking values 1,2,3, ...($n = 1$, called the ground state) corresponding to the number of loops in the standing wave.

Use the model described above to answer the following three questions for a particle moving along the line from $x = 0$ to $x = \alpha$. Take $h = 6.6 \times 10^{-34} Js$ and $e = 1.6 \times 10^{-19}$ C.

Q. If the mass of the particle is $m = 1.0 \times 10^{-30}$kg and $\alpha = 6.6nm$, the energy of the particle in its ground state is closest to

A. 0.8 MeV

B. 8 MeV

C. 80 MeV

D. 800 MeV

Answer: B

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3. When a particle is restricted to move along x-axis between $x = 0$ and $x = a$, where α if of nenometer dimension, its energy can take only certain specific values. The allowed energies of the particle moving in such a restricted region, correspond to the formation of standing waves with nodes at its ends $x = 0$ and $x = a$. The wavelength of this standing wave is related to the linear momentum p of the particle according to the de Broglie relation. The energy of the particle of mass m is related to its linear momentum as $E = \frac{p^2}{2m}$. Thus the energy of the particle can be denoted by a quantum number n taking values 1,2,3, ...($n = 1$, called the ground state) corresponding to the number of loops in the standing wave.

Use the model described above to answer the following three questions for a particle moving along the line from $x = 0$ to $x = \alpha$.

Take $h = 6.6 \times 10^{-34} Js$ and $e = 1.6 \times 10^{-19}$

C

Q. The speed of the particle that can take discrete values is proportional to

A. $n^{-3/2}$

B. n^{-1}

C. $n^{1/2}$

D. n

Answer: D

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4. A neutral atom has the following electronic configuration: $1s^2 2s^2 2p^6 3s^2 3p^5$

How many electrons are in the M shell?

A. 2

B. 6

C. 5

D. 7

Answer: D

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5. A neutral atom has the following electronic configuration: $1s^2 2s^2 2p^6 3s^2 3p^5$

How many protons are in the atomic nucleus?

A. 4

B. 12

C. 7

D. 17

Answer: D

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6. A neutral atom has the following electronic configuration: $1s^2 2s^2 2p^6 3s^2 3p^5$

To which group of the periodic table does this element belong?

A. I

B. VII

C. II

D. VI

Answer: B

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7. An electron in an atom has the following set of quantum numbers:

$n = 3, l = 2, m_l = +1, m_s = +1/2$

What shell is this electron occupying?

A. K shell

B. M shell

C. L shell

D. N shell

Answer: B

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8. An electron in an atom has the following set of quantum numbers:

$n = 3, l = 2, m_l = +1, m_s = +1/2$

In which subshel can the electron be found?

A. s

B. d

C. p

D. f

Answer: B

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9. An electron in an atom has the following set of quantum numbers:

$n = 3, l = 2, m_l = +1, m_s = +1/2$

According to the quantum mechanical picture of the atom, which quantum number(s) could be different for electons in this same atom that have exactly the same energy?

A. n, l, m_l and m_S

B. only l and m_l

C. only l, m_l and m_S

D. only m_l and m_S

Answer: C

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10. Consider the following list of electron configurations:

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

(3) $1s^2 2s^2 2p^6 3s^1$ (4) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

(5) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

Which one of the above configuration represents a neutral atom that readily forms a singly charged positive ion?

A. 1

B. 3

C. 2

D. 4

Answer: B

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11. Consider the following list of electron configurations:

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

(3) $1s^2 2s^2 2p^6 3s^1$ (4) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

(5) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

Which one of the above configurations represents an excited state of a neutral atom?

A. 1

B. 3

C. 2

D. 4

Answer: A

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12. Consider the following list of electron configurations:

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

(3) $1s^2 2s^2 2p^6 3s^1$ (4) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

(5) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

Which one of the above configuration represents a transition element?

A. 1

B. 5

C. 2

D. 4

Answer: B

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Practice Questions Matrix Match

1. Match the statements in Column I labeled as (a), (b), (c), and (d) with those in Column II labeled as (p), (q), (r), and (s). Any given statement in Column I can have correct matching with one or more statements in Column II.

An electron in hydrogen atom moves from $n = 1$ to $n = 2$.

Column I	Column II
(a) Angular momentum	(p) One-forth times
(b) Kinetic energy	(q) Two times
(c) Potential energy	(r) Four times
(d) Mechanical energy	(s) Half times

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2. Match the statements in Column I labeled as (a), (b), (c), and (d) with those in Column II labeled as (p), (q), (r), and (s). Any given statement in Column I can have correct matching with one or more statements in Column II.

Column I	Column II
(a) Lithium atom	(p) 54.4 eV
(b) Helium atom	(q) 13.6 eV
(c) Beryllium atom	(r) 122 eV
(d) Hydrogen atom	(s) 217.6 eV

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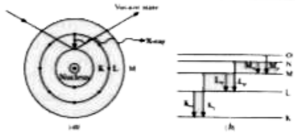
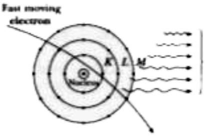
3. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

The x-rays have different penetration power. In the given table, Column I shows their penetration power of x-rays, Column II shows their frequenc and speed and Column III shows their wavelength range and mode of generation.

Column I	Column II	Column III
(I) More penetration power	(i) a few fast-moving electrons penetrate deep into the interior of the atoms of the target material	(J) 
(II) Consists of radiations of all possible wavelengths	(ii) more frequency of the order of ≈ 10[illegible] Hz	(K) more wavelength range (4 Å to 100Å)
(III) Less penetration power	(iii) less frequency of the order of ≈ 10[illegible] Hz	(L) 
(IV) Consists of definite, well defined wavelengths	(iv) few of the fast moving electrons having velocity of about (1/10)[illegible] of the velocity of light may penetrate the surface atoms	(M) lesser wavelength range (0.1 Å to 4Å)

What are the characteristics of hard x-rays?

A. (II) (iii) (M)

B. (III) (ii) (K)

C. (I) (ii) (M)

D. (I) (iii) (J)

Answer: C

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4. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

The x-rays have different penetration power. In the given table, Column I shows their penetration power of x-rays, Column II shows their frequenc and speed and Column III shows their wavelength range and mode of generation.

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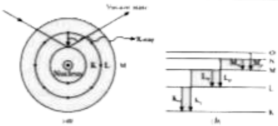
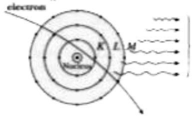
(I) More penetration power	(i) a few fast-moving electrons penetrate deep into the interior of the atoms of the target material	(J) 
(II) Consists of radiations of all possible wavelengths	(ii) more frequency of the order of ≈ 10[illegible] Hz	(K) more wavelength range (4 Å to 100Å)
(III) Less penetration power	(iii) less frequency of the order of ≈ 10[illegible] Hz	(L) Fast moving electron 
(IV) Consists of definite, well defined wavelengths	(iv) few of the fast moving electrons having velocity of about (1/10)[illegible] of the velocity of light may penetrate the surface atoms.	(M) lesser wavelength range (0.1 Å to 4Å)

What are the characteristics of continuous x-rays?

A. (I) (ii) (M)

B. (II) (i) (L)

C. (II) (ii) (K)

D. (III) (iv) (M)

Answer: B

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5. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

The x-rays have different penetration power. In the given table, Column I shows their penetration power of x-rays, Column II shows their frequenc and speed and Column III shows their wavelength range and mode of generation.

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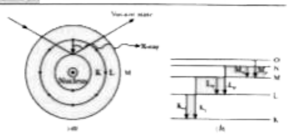
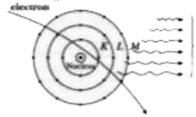
(I) More penetration power	(i) a few fast-moving electrons penetrate deep into the interior of the atoms of the target material	(J) 
(II) Consists of radiations of all possible wavelengths	(ii) more frequency of the order of ≈ $10^{[illegible]}$ Hz	(K) more wavelength range (4 Å to 100Å)
(III) Less penetration power	(iii) less frequency of the order of ≈ $10^{[illegible]}$ Hz	(L) Fast moving electron 
(IV) Consists of definite, well defined wavelengths	(iv) few of the fast moving electrons having velocity of about $(1/10)^{th}$ of the velocity of light may penetrate the surface atoms	(M) lesser wavelength range (0.1 Å to 4Å)

What are the characteristics of soft x-rays?

A. (III) (i) (L)

B. (IV) (i) (J)

C. (III) (iv) (J)

D. (III) (iii) (K)

Answer: D

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6. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

There are different types of lasers. In the given table, Colums I shows the properties of different lasers or material used in lasers, Column II shows the different names of the lasers and Column III shows the uses of different type of lasers.

Column I	Column II	Column III
(I) Glass or crystalline materials are used	(i) Gallium Arsenide	(J) Increases its internal energy
(II) Similar to transistor, also known as laser diodes	(ii) Ruby laser	(K) Used in fibre optic communication
(III) Light supplies energy in the laser medium	(iii) Helium-neon lasers	(L) Used when drilling holes in metals
(IV) Laser light with very high beam quality is required.	(iv) Dye laser	(M) Used in doping

What are the characteristics of solid-state laser?

A. (III) (ii) (L)

B. (I) (ii) (L)

C. (II) (i) (M)

D. (II) (i) (K)

Answer: B

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7. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

There are different types of lasers. In the given table, Colums I shows the properties of different lasers or material used in lasers, Column II shows the different names of the lasers and Column III shows the uses of different type of lasers.

Column I		Column II		Column III	
(I)	Glass or crystalline materials are used	(i)	Gallium Arsenide	(J)	Increases its internal energy
(II)	Similar to transistor, also known as laser diodes	(ii)	Ruby laser	(K)	Used in fibre optic communication
(III)	Light supplies energy in the laser medium	(iii)	Helium-neon lasers	(L)	Used when drilling holes in metals
(IV)	Laser light with very high beam quality is required.	(iv)	Dye laser	(M)	Used in doping

What are the characteristics of semiconductor laser?

A. (I) (iii) (K)

B. (IV) (iii) (J)

C. (I) (ii) (M)

D. (II) (i) (K)

Answer: D

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8. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

There are different types of lasers. In the given table, Colums I shows the properties of different lasers or material used in lasers, Column II shows the different names of the lasers and Column III shows the uses of different type of lasers.

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(I) Glass or crystalline materials are used	(i) Gallium Arsenide	(J) Increases its internal energy
(II) Similar to transistor, also known as laser diodes	(ii) Ruby laser	(K) Used in fibre optic communication
(III) Light supplies energy in the laser medium	(iii) Helium-neon lasers	(L) Used when drilling holes in metals
(IV) Laser light with very high beam quality is required.	(iv) Dye laser	(M) Used in doping

What are the characteristics of liquid state laser?

A. (III) (i) (K)

B. (I) (i) (L)

C. (III) (iv) (M)

D. (I) (iv) (M)

Answer: C

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9. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

Four quantum numbers shows the electronic configuration of the element. In the given table, Column I shows the different values of principal quantum number, Column II shows the different values of angular momentum quantum number and Column III shows the energy levels for different orbitals.

Column I	Column II	Column III
(I) Value of $n = 2$	(i) Value of $l = 0$	(J) Lowest energy
(II) Value of $n = 1$	(ii) Value of $l = 1$	(K) 2*p* orbital have lower energy than 3*s* orbital

Column I	Column II	Column III
(III) Value of $n = 4$	(iii) Value of $l = 2$	(L) Higher energy than 1*s* orbital
(IV) Value of $n = 3$	(iv) Value of $l = 2$	(M) Higher energy than 2*s* orbital.

What are the characteristics of 1s orbital?

A. (I) (ii) (J)

B. (IV) (i) (M)

C. (II) (iv) (K)

D. (II) (i) (J)

Answer: D

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10. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

Four quantum numbers shows the electronic configuration of the element. In the given table, Column I shows the different values of principal quantum number, Column II shows the different values of angular momentum quantum number and Column III shows the energy levels for different orbitals.

Column I		Column II		Column III	
(I)	Value of $n = 2$	**(i)**	Value of $l = 0$	**(J)**	Lowest energy
(II)	Value of $n = 1$	**(ii)**	Value of $l = 1$	**(K)**	$2p$ orbital have lower energy than $3s$ orbital

Column I	Column II	Column III
(III) Value of $n = 4$	(iii) Value of $l = 2$	(L) Higher energy than 1s orbital
(IV) Value of $n = 3$	(iv) Value of $l = 2$	(M) Higher energy than 2s orbital.

What are the characteristics of 2p orbital?

A. (III) (ii) (J)

B. (I) (ii) (K)

C. (II) (iii) (K)

D. (I) (i) (M)

Answer: B

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11. In each equation, there is a table having 3 columns and 4 rows. Based on the table, there are 3 questions. Each question has 4 options (a), (b), (c) and (d), ONLY ONE of these four options is correct.

Four quantum numbers shows the electronic configuration of the element. In the given table, Column I shows the different values of principal quantum number, Column II shows the different values of angular momentum quantum number and Column III shows the energy levels for different orbitals.

Column I		Column II		Column III	
(I)	Value of $n = 2$	(i)	Value of $l = 0$	(J)	Lowest energy
(II)	Value of $n = 1$	(ii)	Value of $l = 1$	(K)	$2p$ orbital have lower energy than $3s$ orbital

Column I		Column II		Column III	
(III)	Value of $n = 4$	(iii)	Value of $l = 2$	(L)	Higher energy than $1s$ orbital
(IV)	Value of $n = 3$	(iv)	Value of $l = 2$	(M)	Higher energy than $2s$ orbital.

What are the characteristics of 2s orbital?

A. (I) (i) (L)

B. (I) (i) (K)

C. (III) (iii) (J)

D. (I) (ii) (M)

Answer: A

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Practice Questions Integer Type

1. How many electron could be accommodated in a g subshell?

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2. Frequency of a photon emitted due to transition of electron of a certain element from $L \to K$shell is found to be $4.2 \times 10^{18} Hz$

Using Moseley 's law, find the atomic number of the element , given that the Rydberg's constant $R = 1.1 \times 10^7 m^{-1}$

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Checkpoint

1. Does the cutoff wavelength $\lambda_{\min}$ of the continous x- ray spectrum increse decrease or remain the same if you (a) increase the kinetic energy of the electrons that strike the x ray target (b) allow the electrons to strike a thin foil rather than a thick block of the target material ,(c) change the target to an element of higher atomic number ?

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