2.LIMITATIONS AND SOMMERFELD THEORY,DEBROGLIES AND SCRODINGER WAVE EQUATION

SOLUTIONS

TEACHING TASK

JEE MAINS LEVEL QUESTIONS

1. Sommerfeld's theory extended Bohr's model of the atom by incorporating:

   A) Wave-particle duality B) Electromagnetic radiation

   C) Elliptical orbits D) Spin angular momentum

Answer:C

Solution:Sommerfeld extended Bohr's model by introducing elliptical orbits (in addition to circular orbits) and applying relativistic corrections to electron motion.

2. How did Sommerfeld modify Bohr's model of the atom to account for elliptical orbits?

   A) Introducing quantized angular momentum

   B) Incorporating spin angular momentum

   C) Introducing quantized energy levels D) Including wave-particle duality

Answer:A

Solution:Sommerfeld introduced quantized angular momentum for elliptical orbits using two quantum numbers:

Principal quantum number (n) for energy.

Azimuthal quantum number (k) for orbital shape.

Spin angular momentum (B) was introduced later by Uhlenbeck and Goudsmit.

Quantized energy levels (C) were already in Bohr's model.

Wave-particle duality (D) was proposed by de Broglie, not Sommerfeld.

3. What feature of Sommerfeld's atomic model distinguishes it from Bohr's model?

   A) Introduction of quantized angular momentum

   B) Incorporation of wave-particle duality

   C) Consideration of elliptical orbits D) Neglect of electron spin

Answer:C

Solution:The key difference was the inclusion of elliptical orbits alongside circular ones.

4. The de Broglie wavelength of a particle is inversely proportional to its:

A) Velocity B) Momentum C) Kinetic energy D) All the above

Answer:B

Solution:De Broglie wavelength (λ) is given by: $\lambda = \frac{h}{p}$

where p = momentum (mass × velocity).

It depends only on momentum, not directly on velocity (A) or kinetic energy (C).

5. If the momentum of a particle is doubled, what happens to its de Broglie wavelength, assuming all other factors remain constant?

A) It is halved B) It is doubled

C) It remains the same D) It becomes four times smaller

Answer:A

Solution:Since $\lambda = \frac{h}{p}$, doubling momentum (p) reduces the wavelength by half.

6. Wave properties are only important for particles having

A) High mass and low velocities B) Low mass and no velocity

C) High mass and high velocities D) Low mass and high velocities

Answer:D

Solution:Wave nature is significant when the de Broglie wavelength is large (comparable to system dimensions).

This occurs for light particles (e.g., electrons) moving at high speeds (low mass, high velocity).

Heavy particles (A, C) have negligible wavelengths, and stationary particles (B) have infinite wavelength (no practical wave behavior).

7. If the wavelength of the electron is numerically equal to the distance travelled by it in 1 sec, then

A) $\lambda = \frac{h}{p}$ B) $\lambda = \sqrt{\frac{h}{m}}$ C) $\lambda = \frac{h}{m}$ D) $\lambda = \sqrt{\frac{h}{p}}$

Answer:B

Solution:Wavelength of electron (λ) = distance travelled in 1 second (d)

Distance travelled in 1 second = velocity (v) × time (t) = v × 1 = v

So, λ = v

Using de Broglie wavelength formula: $\lambda = \frac{h}{mv}$

Since λ = v, we substitute: $v = \frac{h}{mv}$

$$v^2 = \frac{h}{m}$$
$$v = \sqrt{\frac{h}{m}}$$

8. The kinetic energy of electron is $3.0 \times 10^{-25} J$. The wave length of the electron is

A) 7965A^0 B) 4625A^0 C) 91A^0 D) 8967A^0

Answer:D

Solution:kinetic energy of electron is E=$3.0 \times 10^{-25} J$

Mass of electron (m) = 9.1 × 10^{-31} kg

h=6.62x10^{-34}kg

$$\lambda = \frac{h}{\sqrt{2mE}}$$
$$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{(2 \times 9.1 \times 10^{-31} \times 3.0 \times 10^{-25})}}$$
$$\lambda = \frac{6.62 \times 10^{-34}}{7.394 \times 10^{-28}} = 0.8953 \times 10^{-6}$$
$$\lambda = 8.953 \times 10^{-7}$$

Convert to Angstroms (Å)

Since 1 Å = 10^{-10}m,

$\lambda = 8.953 \times 10^{-7}$ =8953 A^0

9. An electron of a velocity '*x*' is found to have a certain wavelength. The velocity to be possessed by the neutron to have half the de Broglie wavelength possessed by electron is :

A) $x/1840$ B) $x/920$ C) $3680x$ D) $x/3680$

Answer:B

Solution:The de Broglie wavelength (λ) for any particle is given by: $\lambda = \frac{h}{p} = \frac{h}{mv}$

For the electron (λ_e): $\lambda_e = \frac{h}{m_e x}$

For the neutron (λ_n):We want the neutron's wavelength to be half of the electron's wavelength:

$$\lambda_n = \frac{\lambda_e}{2}$$

$$\lambda_n = \frac{h}{2m_e x}$$

But the neutron's wavelength is also given by: $\lambda_n = \frac{h}{m_n v_n}$

Equate the Two Expressions for λ:

$$\frac{h}{m_n v_n} = \frac{h}{2m_e x}$$

$$\frac{1}{m_n v_n} = \frac{1}{2m_e x}$$

$$v_n = \frac{2m_e x}{m_n}$$

The mass of a neutron (m_n) is approximately 1840 times the mass of an electron (m_e):

$$m_n = 1840 m_e$$

Substitute into the equation for v_n: $v_n = \frac{2m_e x}{1840 m_e} = \frac{x}{920}$

10. A neutron is moving with a velocity of 1.5×10^6 m/s. What is its de Broglie wavelength?

A) 8.78×10^{-15} m B) 3.98×10^{-15} m

C) 6.62×10^{-15} m D) 1.12×10^{-14} m

Answer: 2.63×10^{-13}

Solution:The de Broglie wavelength (λ) is given by: $\lambda = \frac{h}{p} = \frac{h}{mv}$

$$\lambda = \frac{6.626\times10^{-34}}{1.675\times10^{-27}\times1.5\times10^{6}} = \frac{6.626}{2.5125} = 2.63\times\frac{10^{-34}}{10^{-21}}$$
$$= 2.63\times10^{-13}$$

11. An electron is accelerated through a potential difference of 100 V. What is the de Broglie wavelength of the electron?

A) 1.23×10^{-10} m   B) 6.63×10^{-10} m

C) 3.27×10^{-10} m   D) 8.66×10^{-10} m

Answer:A

Solution:When an electron is accelerated through a potential difference (V), its kinetic energy (KE) is given by:KE=eV

$$KE = \frac{p^2}{2m_e}$$
$$p = \sqrt{2m_e KE}$$
$$p = \sqrt{2\times(9.109\times10^{-31})\times(1.602\times10^{-17})}$$
$$p \approx 5.402\times10^{-24}$$

$$\lambda = \frac{6.626\times10^{-34}}{5.402\times10^{-24}} \approx 1.227\times10^{-10} m$$

12. If $E_{e,}E_\alpha$, and E_p represents the kinetic energies of an electron alpha particle and a proton respectively, each moving with same deBroglie wavelength then :

A) $E_e = E_\alpha = E_p$ B) $E_e > E_\alpha > E_p$ C) $E_\alpha < E_P < E_e$ D) $E_e = E_P < E_n$

Answer:C

Solution: $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$

Since all three particles have the same wavelength, we can write:

$$\frac{h}{\sqrt{2m_e E_e}} = \frac{h}{\sqrt{2m_p E_p}} = \frac{h}{\sqrt{2m_\alpha E_\alpha}}$$

Relate Kinetic Energies to Masses

$$\sqrt{2m_eE_e} = \sqrt{2m_pE_p} = \sqrt{2m_\alpha E_\alpha}$$

$$\sqrt{m_eE_e} = \sqrt{m_pE_p} = \sqrt{m_\alpha E_\alpha}$$

Square both sides to eliminate the square roots:

$$m_eE = m_pE_p = m_\alpha E_\alpha$$

Compare Masses and Energies

$Electron(m_e): 9.109\times10^{-31} kg$

$Proton(m_p): 1.673\times10^{-27} kg$

$Alphaparticle(m_\alpha): 6.644\times10^{-27} kg(\approx 4timesprotonmass)$

$fromtheEquation$

$m_eE_e = m_pE_p = m_\alpha E_\alpha, wecanwrite:$

$$E_e = \frac{m_p}{m_e}E_p, E_p = \frac{m_\alpha}{m_p}E_\alpha$$

Substitute the masses: $E_e = \frac{1.673\times10^{-27}}{9.109\times10^{-31}}E_p \approx 1836E_p$

$E_p = \frac{6.644\times10^{-27}}{1.673\times10^{-27}}E_\alpha \approx 4E_\alpha$

$E_e \approx 1836E_p and$

$E_p \approx 4E_\alpha$

$E_e >> E_p > E_\alpha$ or $E_\alpha < E_P < E_e$

13. Calculate the wavelength (in nm) associated with a proton moving at $1.0\times10^3 m/s$. The mass of proton is $1.67\times10^{-27} kg$ and h is $6.63\times10^{-34} Js$

A)0.032 nm B) 2.5 nm C) 14.0 nm D) 0.4 nm

Answer:D

Solution:
$$\lambda = \frac{h}{mv}$$
$$\lambda = \frac{6.63\times10^{-34}}{1.67\times10^{-27}\times1.0\times10^{3}} = 3.97\times10^{-10}$$
$$1nm = 10^{-9}nm$$
$$\lambda = 3.97\times10^{-10} = 0.397$$

14. The de-Broglie wavelength for a proton with a velocity 15% of the speed of light is :

A) $8.8\times10^{-12}m$ B) $8.8\times10^{-15}cm$ C) $8.8\times10^{-15}m$ D) $4.4\times10^{-15}cm$

Answer:C

Solutin:15 % of Speed of light=$0.15\text{x}3\text{x}10^{8}=4.5\text{x}10^{7}$

$$\lambda = \frac{h}{mv}$$
$$\lambda = \frac{6.63\times10^{-34}}{1.67\times10^{-27}\times4.5\times10^{7}} = 0.8822\times10^{-14} = 8.822\times10^{-15}m$$

15. The velocities of two particles A and B are 0.05 and 0.02m/s respectively. The mass of B is five times the mass of A) The ratio of their de-Broglies wavelength is
A) 2 : 1 B) 1 : 4 C) 1 : 1 D) 4 : 1

Answer:A

Solution: Write Wavelengths for Particles A and B

$$\lambda_A = \frac{h}{m_A v_A}$$
$$\lambda_B = \frac{h}{m_B v_B}$$

Substitute Given Values

Given:v_A=0.05m/s ,v_B=0.02m/s,$m_B=5m_A$

$$\lambda_A = \frac{h}{m_A\times0.05}$$
$$\lambda_B = \frac{h}{5m_A\times0.02}$$

$$\frac{\lambda_A}{\lambda_B} = \frac{\dfrac{h}{m_A \times 0.05}}{\dfrac{h}{5m_A \times 0.02}} = \frac{0.1}{0.05} = \frac{2}{1}$$

16. The mass of an electron is m, its charge e and it is accelerated from rest through a potential difference V. The velocity of electron will be calculated by formula :

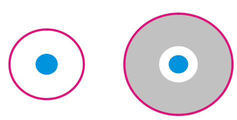
A) $\sqrt{V/m}$ B) $\sqrt{eV/m}$ C) $\sqrt{(2eV/m)}$ D) None of these

Answer:C

Solution:

$$KE = \frac{1}{2}mv^2$$
$$KE = eV$$
$$eV = \frac{1}{2}mv^2$$
$$2eV = mv^2$$
$$v^2 = \frac{2ev}{m}$$
$$v = \sqrt{\frac{2ev}{m}}$$

17. The probability density plots of 1s and 2s orbitals are given in figure



1s 2s

The density of dots in region represents the probability density of finding electrons in the region.On the basis of above diagram which of the following statements is incorrect?

A) 1s and 2s orbitals are spherical in shape

B) The probability of finding the electron is maximum near the nucleus.

C) The probability of finding the electron at a given distance is equal in all directions.

D) The probability density of electrons for 2s orbitals decreases uniformly as distance from the nucleus increases.

Answer:B,D

Solution:Option A: Correct.

Both 1s and 2s orbitals are s-orbitals, and all s-orbitals are spherical in shape.

Option B: Partially Correct for 1s, Incorrect for 2s.

For 1s, the maximum probability is at the nucleus.

For 2s, there is a node (a region of zero probability) near the nucleus, and the probability increases again further away.

So, in 2s, the electron is not most likely to be found near the nucleus, which contradicts this statement.

C) True:

This is the definition of spherical symmetry. The probability density depends only on the distance from the nucleus, not the direction (since it's an s-orbital).

D) False statement, but we must be careful:

Actually, in 2s, the probability density does not decrease uniformly — it first increases, reaches a maximum, then drops to zero at the node, and increases again, then finally decreases.

18. In a main energy level, the orbital with more number of nodal planes will be ......

A) Higher energy B) Lower energy C) Either 1 or 2 D) Neither 1 nor 2

Answer:A

Solution:Nodal planes are regions where the probability of finding an electron is zero.

Orbitals with more nodal planes have higher energy because they exhibit more complex wavefunctions and greater angular momentum (e.g., p, d, f orbitals).

19. Choose the correct statement among the following :

A) ψ^2 represents the atomic orbital

B) The number of peaks in radial distribution is n-1

C) A node is a point in space around nucleus where the wave function ψ has zero value

D) All of the these

Answer:B,C

Soution:Option A:Incorrect.

φ (psi) represents the atomic orbital (wavefunction).

φ^2 represents probability density, not the orbital itself.

Option B:Correct.

The number of peaks in radial distribution is n-l

Option C:Correct.

A node is a point/region where wave function ψ has zero value

20. Which of the following statements is correct?

A) An orbital describes the path of an electron in an atom

B) An orbital is a region where the electron is not located

C) An orbital is a function which gives the probabilities of finding the electron in a given region

D) All the above

Answer:C

Solution:C) Correct

This is the quantum mechanical definition of an orbital.

An orbital is described by a wave function (ψ). The square of the wave function, ψ^2, gives the probability density of finding the electron at a point in space

21. For an electron in a hydrogen atom, the wave function ψ is proportional to exp, where a_0 is the Bohr's radius. What is the ratio of the probability of finding the electron at the nucleus to the probability of finding it at a_0?

A) e B) e^2 C) $1/e^2$ D) zero

Answer:B

Solution:We are given that the wave function ψ (r) for the electron in a hydrogen atom is proportional to: $\psi(r) \alpha e^{-r/a_0}$

Where: a_0 is the Bohr radius

r is the distance from the nucleus

The probability density is given by the square of the wave function: $P(r)\alpha |\psi(r)|^2 = (e^{-r/a_0})^2 = e^{-2r/a_0}$

$$P(r)\alpha |\psi(r)|^2 = (e^{-r/a_0})^2 = e^{-2r/a_0}$$

$$\frac{P(0)}{P(a_0)} = \frac{e^{-2(0)/a_0}}{e^{-2a_0/a_0}} = \frac{e^0}{e^{-2}} = e^2$$

JEE ADVANCED LEVEL QUESTIONS

MULTI CORRECT ANSWER TYPE

1. Which of the following statements are consistent with Sommerfeld's extension of the Bohr model?

A) Electrons can occupy orbits with non-integer values of angular momentum.

B) Electrons can occupy elliptical orbits with different eccentricities.

C) Energy levels of electrons are quantizeD)

D) Electrons move in random paths within the atom.

Answer:A,B,C

Solution:A) True. Sommerfeld introduced fractional quantum numbers, allowing non-integer angular momentum values.

B) True. His model included elliptical orbits (with quantized eccentricities) alongside Bohr's circular orbits.

C) True. Energy levels remained quantized, but with fine structure due to relativistic effects.

D) False. Electrons follow defined quantized orbits, not random paths.

2. Which of the following statements regarding de Broglie waves is not true?

A) They are electromagnetic waves.

B) They have a frequency proportional to the particle's energy.

C) They can be observed macroscopically.

D) They have a wavelength inversely proportional to the particle's momentum.

Answer:A,C

Solution:A) False (Not True). De Broglie waves are matter waves, not electromagnetic waves.

B) True. Frequency υ =E/h, where E is the particle's energy.

C) False (Not True). Macroscopic objects have negligible wavelengths (e.g., a baseball's $\lambda \approx 10^{-34}$m).

D) True. Wavelength λ=h/p, where p is momentum.

REASON AND ASSERTION TYPE

3. **A :** An electron cannot exist in the nucleus

R : The deBroglie wavelength of an electron is much smaller than the diameter of the nucleus

Answer:C

Solution:Assertion (A) is true. Electrons are not found in the nucleus due to quantum mechanical constraints (e.g., high energy required for confinement).

Reason (R) is false. The de Broglie wavelength of an electron (˜ 10^{-12} m for typical energies) is much larger than the nucleus diameter (˜ 10^{-15} m).

4. **A :** deBroglie equation has significance for any microscopic or submicroscopic particles

R : deBroglie wavelength is inversely proportional to the mass of the object.

Answer:A

Solution:Assertion (A) is true. The de Broglie equation (λ=h/p) applies to all particles (e.g., electrons, protons, even large molecules like C_{60}).

Reason (R) is true and explains A. For a given velocity, $\lambda \alpha$ 1/m (since p=mv). This is why macroscopic objects (large m) have negligible wavelengths.

5. **A :** The P_x orbital has maximum electron density along the x axis and its nodal plane is yz plane

R : For a given atom, for all values of n, the p-orbitals have the same shape, but the overall size increase as n increases

Answer:B

Solution:Assertion (A) is true. This describes a p_x orbital, which has:

Maximum density along the x-axis (lobes).

A nodal plane (yz-plane) where ψ=0.

Reason (R) is true but does not explain A. While p-orbitals retain their dumbbell shape across shells (n), this fact is unrelated to the directional property stated in A.

6. **A :** Electrons may be considered as particles and waves

R : An electron in an atom may be described as occupying at atomic orbital or by a wave function ψ, which is a solution to the schrodinger wave equation

Answer:A

Solution:Assertion (A) is true. Electrons exhibit wave-particle duality (e.g., diffraction patterns like waves, discrete collisions like particles).

Reason (R) is true and explains A. The wave function (ψ) describes the electron's wave-like behavior, while orbitals represent quantized energy states (particle-like).

COMPREHENSION TYPE

7. According to de Broglie's hypothesis, which of the following is true about particles?

A) They only exhibit wave-like properties.

B) They only exhibit particle-like properties.

C) They exhibit both particle-like and wave-like properties.

D) They exhibit neither particle-like nor wave-like properties.

Answer:C

Solution:The passage explicitly states that de Broglie's hypothesis proposed the dual nature of matter, where particles (like electrons) exhibit both particle-like and wave-like properties.

This is confirmed by experiments such as electron diffraction, which demonstrate wave behavior (e.g., interference patterns) for particles.

8. What does the equation λ = h/p signify in de Broglie's theory?

A) It defines the velocity of particles. B) It illustrates the energy of particles.

C) It demonstrates the wave nature of particles. D) It calculates the mass of particles.

Answer:C

Solution:The equation λ = h/p(de Broglie wavelength) directly links a particle's momentum (p=mv) to its wavelength (λ), showing that particles have wave-like characteristics.

It does not define velocity (A), energy (B), or mass (D). Instead, it quantifies the wave nature of particles (C).

INTEGER TYPE

9. If a neutron has a kinetic energy of 50 eV, what is its de Broglie wavelength?

Answer: $1.278\times10^{-12}m$

Solution: $\lambda=\frac{h}{p}=\frac{h}{\sqrt{2mK}}$

Convert K.E. to joules

$$K=50eV=50\times1.602\times10^{-19}=8.01\times10^{-18}J$$

$$\lambda=\frac{6.626\times10^{-34}}{\sqrt{2\times1.675\times10^{-27}\times8.01\times10^{-18}}}$$

$$\lambda=\frac{6.626\times10^{-34}}{\sqrt{2.682\times10^{-44}}}=\frac{6.626\times10^{-34}}{5.18\times10^{-22}}\approx1.278\times10^{-12}m$$

10. An alpha particle (helium nucleus) has a mass of 6.64 x 10^{-27} kg. What is the de Broglie wavelength of an alpha particle moving at a velocity of 2.0 x 10^{7} m/s?

Answer: $4.99\times10^{-15}m$

Solution:Given m=6.64 x 10^{-27} kg

v=2.0 x 10^{7} m/s

$$\lambda=\frac{h}{mv}=\frac{6.626\times10^{-34}}{6.64\times10^{-27}\times2.0\times10^{7}}$$

$$\lambda=\frac{6.626\times10^{-34}}{1.328\times10^{-19}}\approx4.99\times10^{-15}m$$

MATRIX MATCHING TYPE

11.**Answer:I-C,II-D,III-A,IV-B**

List - I	**List - II**
I) Radial probability distribution curve of 3s orbital	C)3 peaks, 2 radial nodes
II) Distance of maximum probability of 1s electron	D) $0.53A^0$
III) Radial node for a 2s electron	A) $1.1A^0$
IV) No spherical nodes	B)1s orbital

Solution:I) Radial probability distribution curve of 3s orbital

The 3s orbital has:3 peaks (regions of high probability),2 radial nodes (where probability = 0).

II) Distance of maximum probability of 1s electron

The 1s orbital has a single peak in its radial distribution curve, corresponding to the Bohr radius (˜ 0.529 Å) for hydrogen.

III)The 2s orbital has one radial node.

$$\psi_{2s} = \frac{1}{2\sqrt{2\pi}}\sqrt{\frac{1}{a_0}}(2-\frac{1}{a_0})e^{-\frac{r}{2a_0}}$$

$$|\psi_{2s}|^2 = 0, 2-\frac{1}{a_0} = 0$$

$$2a_0 = r$$

$$a_0 = bohrsradius$$

$$r = 2(0.53) = 1.16A^0$$

IV) No spherical nodes : The 1s orbital has no spherical nodes.

LEARNERS TASK

CONCEPTUAL UNDERSTANDING QUESTIONS

1. The splitting of spectral lines of an atom into a group of fine lines under the influence of a magnetic field is called

A) Zeeman Effect B) Stark Effect C) Both D) none

Answer:A

Solution:The Zeeman Effect describes the splitting of spectral lines due to an external magnetic field.

2. Sommers feld proposed that electron might be rotated in

A)elliptical B) circular orbits C) both 1 and 2 D) none

Answer:C

Solution:Sommerfeld extended Bohr's model by introducing elliptical orbits alongside circular ones.

3. Angle of revolution is known as

A) azimuthal angle B) radial velocity C) angular velocity D) trasverse

Answer:A

Solution: The azimuthal angle describes the angular position in orbital motion.

4. The relation between prinicpal (n) and azimuthal(l) quantum number is

A) n/ℓ B) ℓ/n C) $v_r + n\varphi$ D)v_r+n

Answer:n-1

Solution:The relation between prinicpal (n) and azimuthal(l) quantum number is

l=n-1

5. According to summerfeld n^{th} shell of Bohr has

A) n-1subshells B) n subshells C) n+1 subshells D) n^2 subshells

Answer:A

Solution:The azimuthal quantum number l ranges from 0 to n-1.

6. Sommerfeld model gives introduction of

A) circular orbits B)elliptical orbits C) stationary orbits D) none

Answer:B

Solution: His key contribution was adding elliptical orbits to Bohr's circular orbits.

7. According to Sommerfeld theory, which of the following properties of an atom is quantized?

A) Mass B) Energy C) Volume D) Temperature

Answer:B

Solution:Energy levels remain quantized in Sommerfeld's model, with fine structure.

8. Sommerfeld's theory predicts the existence of:

A) Electron shells B) Atomic orbitals

C) Electron spin D) Energy levels within energy levels (fine structure)

Answer:D

Solution:His model explained fine structure by quantizing both energy and angular momentum.

9. The momentum of electron is

A) Directly proportional to wave length B) Inversly proportional to wave number

C) Inversly proportional to wave length D) Unable to be determined

Answer:C

Solution:From de Broglie's equation λ=h/p, momentum

p is inversely proportional to λ.

10. The de Broglie wavelength relates to applied voltage as :

A) $\lambda = \frac{12.3}{\sqrt{h}}\overset{0}{A}$ B) $\lambda = \frac{12.3}{\sqrt{V}}\overset{0}{A}$ C) $\lambda = \frac{12.3}{\sqrt{E}}\overset{0}{A}$ D) Both (B) and (C)

Answer:D

Solution: $\lambda = \frac{h}{\sqrt{2meV}} \rightarrow \lambda(inA^0) = \frac{12.3}{\sqrt{V}}A^0$

The kinetic energy E=eV, so $\lambda = \frac{12.3}{\sqrt{E}}A^0$

11. According to de Broglie's concept, the circumference of each electron of which must be equal to

A) Diameter of a electron B) The wave length of an electron

C) The integral no of electron wavelength D) Planck's constant divided by 2

Answer:C

Solution:For stable orbits, the circumference 2πr must fit whole-number multiples of λ.

12. Which one of the following expressions represent the electron probability function (D)

A) $4\pi r\,dr\,\psi^2$ B) $4\pi r^2\,dr\,\psi$ C) $4\pi r^2\,dr\,\psi^2$ D) $4\pi r\,dr\,\psi$

Answer:C

Solution: electron probability function (D) $= 4\pi r^2\,dr\,\psi^2$

13. The probability of finding an electron in an orbital is approximately?

A) 95% B) 50% C) 60% D) 25%

Answer:A

Solution:Orbitals define regions where there is ~95% probability of finding an electron.

14. In the Schrodinger wave equation ψ represents

A) Orbitals B) Wave function C) Amplitude function D) Both 2 & 3

Answer:B

Solution: ψ is the wave function, a mathematical description of the electron's state.

15. The electron density between 1s and 2s is

A) High B) Low C) Zero D) Abnormal

Answer:C

Solution: Radial nodes exist between 1s and 2s orbitals, resulting in zero electron density.

16. The basis of quantum mechanical model of an atom is

A) Angular momentum of electron B) Qantum numbers

C) Dual nature of electron D) Black body radiation

Answer:C

Solution:The model relies on wave-particle duality, described by Schrödinger's equation.

JEE MAINS LEVEL QUESTIONS

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1. The velocity of an electron with de Broglie wavelength of 1.0×10^2 nm is :

A) $7.2 \times 10^5 cm/\sec$ B) $72 \times 10^5 cm/\sec$ C) $7.2 \times 10^4 cm/\sec$ D) $3.6 \times 10^5 cm/\sec$

Answer:A

Solution:de Broglie wavelength = 1.0×10^2 nm=1.0×10^{-7}m

Mass of electron(m_e)=9.11×10^{-31} kg

Planck's constant (h)=6.626×10^{-34}Js

$$\lambda = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda}$$

$$v = \frac{6.626 \times 10^{-34}}{(9.11 \times 10^{-31})(1.0 \times 10^{-7})} = 7.27 \times 10^3 m/s$$

2. The wave length of a electron with mass $9.1 \times 10^{-31} kg$ and kinetic energy $3.0 \times 10^{-25} J$ is

A) 89.67nm B) 8.96nm C) 456.7nm D) 896.7nm

Answer:B

Solution:Planck's constant (h)=6.626×10^{-34}Js

Mass of electron (m)= 9.1×10^{-31} kg

$$\lambda = \frac{h}{\sqrt{2mK}}$$

Assuming the question expects a standard calculation, the correct option is likely (B) 8.96 nm (but the exact value depends on K).

3. A cricket ball of 0.5 Kg is moving with a velocity of 100m per seC) the wavelength associated with its motion is

A) $1/100$ m B) 6.6×10^{-34} m C) 1.32×10^{-35} m D) 6.6×10^{-28} m

Answer:C

Solution: $\lambda = \frac{h}{mv}$

Mass (m) = 0.5 kg

Velocity (v) = 100 m/s

Planck's constant (h) = 6.626×10^{-34} Js

$$\lambda = \frac{6.626\times10^{-34}}{(0.5)(100)} = 1.325\times10^{-35}\, m/s$$

4. If moving with equal speeds, the longest wavelength of the following matter waves is that for a (an)

A) Electron B) α-particle C) Proton D) Neutron

Answer:A

Solution:The lightest particle has the longest wavelength.Electron (lightest among the options).

5. The momentum of radiation of wavelength 0.33 nm is .... kgm sec^{-1}

A) 2 x 10^{-24} B) 2 x 10^{-12} C) 2 x 10^{-6} D) 2 x 10^{-48}

Answer:A

$$\lambda = 0.33nm = 0.33\times10^{-9}\, m$$

$$\lambda = \frac{h}{p}$$

Solution: $p = \frac{h}{\lambda}$

$$\lambda = \frac{6.626\times10^{-34}}{0.33\times10^{-9}} = 2\times10^{-24}\, kgm/s$$

6. $\Psi^2(psi)$ the wave function represents the probability of finding electron. Its value depends

A) Inside the nucleus B) Far from the nucleus

C) Near the nucleus D) Upon the type of orbital

Answer:D

Solution:The wave function $\Psi^2(psi)$ depends on the orbital and its coordinates.

7. The number of radial nodes, nodal planes for an orbital with n = 4 ; l = 1 is

A) 3, 1 B) 2, 1 C) 2, 0 D) 4, 0

Answer:B

Solution:Radial nodes = n-l-1=4-1-1=2

Nodal planes l=1

8. The number of angular and radial nodes of 4d orbital respectively are (EAM-201D)

A)3,1 B)1,2 C)3,0 D)2,1

Answer:D

Solution:For 4d: n=4,l=2

Radial nodes = n-l-1=1

Angular nodes = l=2

9. The number of radial nodes of 3s and 2p orbitals respectively are

A)0,2 B)2,0 C)1,2 D)2,1

Answer:B

Solution:Radial nodes = n-l-1

For 3s (n=3,l=0): Radial nodes = 3-0-1=2

For 2p (n=2,l=1): Radial nodes = 2-1-1=0

10. In the plots of radial distribution function for the hydrogen 3s orbital versus 'r', the no. of peaks are

A) 3 B) 2 C) 1 D) 0

Answer:A

Solution:For 3s, the number of peaks = principal quantum number =n=3.

11. Which of the following conditions is incorrect for

A) ψ must be single valued at any particular point B) ψ must be positive

C) ψ must be a continuous function of its coordinates D) None of the above

Answer:B

Solution: ψ must be finite, single-valued, continuous, and can be positive or negative (but $|\psi^2|$ must be positive).

12. Which of the following statement(s) is/are correct about angular nodes

A) They are independent from the radial wave function

B) They are directional in nature

C) The number of angular nodes of orbital is equal to azimuthal quantum number.

D) All are correct

Answer:D

Solution:Angular nodes are directional (depend on l) and independent of radial wavefunction.

Number of angular nodes = l.

13. Which one of the following conditions is incorrect for a well behaved wave function (ψ)

A) ψ must be finite B) ψ must be single valued

C) ψ must be infinite D) ψ must be continuous

Answer:C

Solution: ψ must be finite, single-valued, continuous, and can be positive or negative (but $|\psi^2|$ must be positive).

14. Which of the following statements on the atomic wave function ψ is not correct?

A) ψ may be a real valued wave function

B) ψ may be in some cases be a complex function

C) ψ has a mathematical significance only

D) ψ is proportional to the probability of finding an electron

Answer:D

Solution: ψ can be real or complex.

$|\psi^2|$ (not ψ) gives probability density.

JEE ADVANCED LEVEL QUESTIONS

MULTI CORRECT ANSWER TYPE

1. According to de Broglie's hypothesis, which of the following statements is true regarding the velocity of a particle?

   A) It cannot be determineD)

   B) It is inversely proportional to its wavelength.

   C) It is directly proportional to its wavelength.

   D) It is unrelated to its wavelength.

Answer:B

Solution: $\lambda = \dfrac{h}{mv}$

Thus, velocity is inversely proportional to wavelength

REASON AND ASSERTION TYPE

2. A : There are two nodal regions in 3s-orbital.

   R : There is no nodal plane in 3s-orbital.

Answer:A

Solution:3s orbital has 2 radial nodes (nodal regions where the probability density is zero).

Number of radial nodes = n-l-1=3-0-1=2.

Nodal planes are associated with angular nodes (which depend on l).

Since l=0 for s-orbitals, there is no nodal plane.

3. A : A spectral line will be observed for a $2p_x – 2p_y$ transition

   R : The energy of $2p_x$ and $2p_y$ orbitals is the same

Answer:D

Solution:$2p_x$ and $2p_y$ orbitals are degenerate (same energy in the absence of a magnetic/ electric field).

No transition occurs between them because they have the same energy.

Spectral lines appear only when there is an energy difference (e.g., $2p \rightarrow 1s$).

4. A : ψ indicates the amplitude of electron - wave

   R : ψ^2 denotes probability of finding an electron in the space around the nucleus

Answer:A

Solution: ψ (wave function) represents the amplitude of the electron's matter-wave.

ψ^2 (probability density) gives the probability of finding the electron at a given point.

5. A : The electronic configurations in which all of the orbitals of the same sub shell are either completely filled or are exactly half filled are more stable

R : The completely filled or exactly half filled shells possess a symmetrical distribution of electrons and allow their maximum number of exchanges

Answer:A

Solution:Half-filled and fully filled subshells are more stable due to:

Symmetry (balanced electron distribution).

Exchange energy maximization (more unpaired electrons in half-filled cases lead to greater stabilization).

INTEGER TYPE

6. Calculate the de Broglie wavelength of a baseball (mass = 0.145 kg) traveling at a speed of 40 m/s.

Answer: 1.142×10^{-34}

Solution:
$$\lambda = \frac{h}{mv}$$
$$\lambda = \frac{6.626\times10^{-34}}{0.145\times40} = 1.142\times10^{-34} m$$

7. If an electron has a de Broglie wavelength of 0.01 nm, what is its momentum?

Answer: 6.626×10^{-23}

Solution:Wavelength (λ) = 0.01 nm =0.01 x 10^{-9}m=1 x 10^{-11}m

$$\lambda = \frac{h}{p}$$
$$p = \frac{h}{\lambda}$$
$$p = \frac{6.626\times10^{-34}}{1\times10^{-11}} = 6.626\times10^{-23} kgm/s$$

COMPREHENSION TYPE

According to de Broglie's theory, particles exhibit both wave-like and particle-like behavior. The wavelength (λ) associated with a particle, such as an electron, can be calculated using the de Broglie wavelength equation:

$$\lambda = \frac{h}{p}$$

Where:

λ = de Broglie wavelength

h = Planck's constant (6.626×10^{-34} m^2 kg/s)

p = momentum of the particle (kg m/s)

Consider an electron with a momentum of 3.0×10^{-24} kg m/s.

8. If the momentum of the electron is doubled while its mass remains constant, what will happen to its de Broglie wavelength?

A) It will become half. B) It will double.

C) It will remain the same. D) It will increase four times.

Answer:A

Solution: $\lambda = \frac{h}{p}$

If the momentum of the electron is doubled while its mass remains constant, what will happen to its de Broglie wavelength become half.

If the momentum of the electron is doubled while its mass remains constant, what will happen to its de Broglie wavelength will become half.

9. If an electron and a proton have the same momentum, which of the following statements is true regarding their de Broglie wavelengths?

A) The electron will have a longer de Broglie wavelength.

B) The proton will have a longer de Broglie wavelength.

C) Both will have the same de Broglie wavelength.

D) It depends on the mass of the particle.

Answer:C

Solution: $\lambda = \frac{h}{p}$

Since h is constant and p is the same for both particles, depends only on p, not mass.

Thus, both particles will have the same de Broglie wavelength, regardless of their masses.

MATRIX MATCHING TYPE

10.**Answer:A-D,B-E,C-B,D-A**

Solution:

List - I	**List - II**
A) nodal plane	D) Probability of e^- is zero
B) p-orbital	E) Dumb bell
C) deBroglie	B) $\lambda = \frac{h}{mv}$
D) Kinetic energy	A) $\frac{Ze^2}{2r}$
	C) Spherical

KEY

			TEACHING TASK						
		JEE MAINS LEVEL QUESTIONS							
1	2	3	4	5	6	7	8	9	10
C	A	C	B	A	D	B	D	B	2.63×10^{-13}
11	12	13	14	15	16	17	18	19	20
A	C	D	C	A	C	B,D	A	B,C	C
21									
B									
		JEE ADVANCED LEVEL QUESTIONS							
1	2	3	4	5	6	7	8	9	
A,B,C	A,C	C	A	B	A	C	C	1.278x10^-12	
10		11							
4.99x10^-15		I-C,II-D,III-A,IV-B							
			LEARNERS TASK						
		CONCEPTUAL UNDERSTANDING QUESTIONS							
1	2	3	4	5	6	7	8	9	10
A	C	A	n-1	A	B	B	D	C	C
11	12	13	14	15	16				
C	C	A	B	C	C				
			JEE MAINS LEVEL QUESTIONS						
1	2	3	4	5	6	7	8	9	10
A	B	C	A	A	D	B	D	B	A
11	12	13	14						
B	D	C	D						
			JEE ADVANCED LEVEL QUESTIONS						
1	2	3	4	5	6		7		8
B	A	D	A	A	1.14x10^-34		6.626x10^-23		A
9	10								
C	A-D,B-E,C-B,D-A								