Quantum Mechanics Chemistry Questions with Solutions

Q1. Choose the wrong statement about the spin of an electron, according to quantum mechanics:

a) It is related to intrinsic angular momentum.
b) Spin is the rotation of an electron about its own axis.
c) Value of the spin quantum number must not be 1.
d) +1/2 value of spin quantum number represents up spin.

Correct Answer. (b) Spin is the rotation of an electron about its own axis.
Explanation. According to quantum mechanics, an electron's spin is related to intrinsic angular momentum; therefore, the value of a spin quantum number cannot be 1 because its -½ and +½ value represents the spin of an electron.

Q2. The Quantum Mechanical Model of the atom was proposed by:

a) Louis de Broglie
b) Erwin Schrodinger
c) Neil Bohr
d) Werner Heisenberg

Correct Answer. (b) Erwin Schrodinger.

Q3. The wavelength of the matter waves is independent of:

a) mass
b) velocity
c) charge
d) momentum

Correct Answer: (c) charge

Q4. Assuming the velocity to be the same, which particle is having longest wavelength

a) an electron
b) a proton
c) a neutron
d) an α-particle

Correct Answer: an electron

Q5. The uncertainty principle states that the error in measurement is due to-

a) dual nature of particles
b) due to the small size of particles
c) due to large size of particles
d) due to error in measuring instrument

Correct Answer: (b) dual nature of particles.

Q6. If the uncertainty in the velocity of a moving object is 1.0×10^{-6} ms^{-1} and the uncertainty in its positions is 58 m, the mass of this object is approximately equal to that of:

a) deuterium
b) lithium
c) electron
d) helium

Correct Answer. (c) electron.

Q7. Define the law of Stefan-Boltzmann.

Answer. The Stefan-Boltzmann Law
This law states that the radiant energy (E) of the body is directly proportional to the fourth power of the temperature (T) of the body.

$E \propto T^4$
$W = \sigma T^4$

Where σ = Stefan Constant, given by $\sigma = \frac{2\Pi^5 K_B^4}{15h^3c^2}$

Q8. Mention the uses of an electron microscope.

Answer. The uses of an electron microscope are as follows-

- It has numerous applications in biology, metallurgy, physics, chemistry, medicine, and engineering.
- It is used to determine the complicated crystal structures.
- It is employed in the investigation of celluloid.
- It is used to investigate the structure of microorganisms such as viruses and bacteria.

Q9. Explain Planck's hypothesis or what are the postulates of Planck's quantum theory?

Answer.

- Electrons in a black body are assumed to be simple harmonic oscillators.

- The oscillators will not continuously emit energy.
- They emit radiation in discrete quanta of magnitude 'hɣ'.
- E = nhɣ, where n=1, 2, 3,.....

Q10, What is the wavelength associated with a photon of a light with the energy is 3.6×10^{-19} J?

Answer. E = hμ = hc/λ

$$3.6 \times 10^{-19} J = \frac{(6.626 \times 10^{-34} Js)\,(3 \times 10^{8} ms^{-1})}{\lambda}$$

λ = 0.55 × 10^{-7} m = 550 nm.

Q11. Describe Planck's three experimental observations that explain the photoelectric effect.

Answer. "When a specific frequency of light shines on a clean metal surface, electrons are ejected from the metal." Experiment results show that:

1. The number of electrons ejected is proportional to the light intensity.
2. The frequency of the ejected light is proportional to the kinetic energy of the ejected electrons.
3. If the frequency of the light is less than a certain value, known as the threshold frequency, no electrons can be ejected (nu_o).

Q12. What is the difference between classical and quantum mechanics? Provide the equation relating the energy of emitted radiation to frequency.

Answer. According to classical mechanics, the radiant energy produced by oscillating objects is continuous. According to quantum mechanics, their energy can be thought of as existing in discrete levels.
E = hμ is the equation.
Energy is released in discrete multiples of hμ, where h equals Planck's constant.

Q13. State Heisenberg's uncertainty principle. Give its mathematical expression.

Answer. Heisenberg's uncertainty principle states that the position and momentum of microscopic moving particles cannot be determined with accuracy or certainty at the same time.
Its mathematical expression is-
Δx × ΔP ≥ h/4π
Δx = uncertainty in the position
ΔP = uncertainty in the omentum
h = Planck's constant

Q14. An electron and a photon each have a wavelength of 1.00 nm. Find
(a) their momentum,

(b) the energy of the photon, and
(c) the kinetic energy of the electron.

Answer.
(a) According to De Broglie's hypothesis,
p = h/λ

$$p = \frac{6.62 \times 10^{-34}}{1 \times 10^{-9}} = 6.62 \times 10^{-25} kg - m/s$$

The value will remain the same irrespective of electron or photon.

(b) λ = 1nm
E = hc/λe = 1243.1 eV = 1.243 KeV

(c) Momentum, p = h/λ = 6.63 × 10^{-25} kg-m/s
K.E of electron is $P^2/2m$ =2.415 × 10^{-19} J =1.51 eV.

Q15. Find the uncertainty in the position of an electron when the mass of an electron is 9.1×10^{-28} g and the uncertainty in velocity is equal to 2×10^{-3} cm/sec.

Answer. Δx × ΔP ≥ h/4π
ΔP =mΔV = 9.1 × 10^{-28} gm × 2 × 10^{-3} cm/sec = 1.82 × 10^{-30} g-cm/sec = 1.82 × 10^{-35} kg-m/sec
Therefore, Δx = h/4πΔP = 2.9 m = 2.9 × 10^2 cm.

Practise Questions on Quantum Mechanics

Q1. The equation of motion of matter-wave was derived by:

a) Heisenberg
b) Bohr
c) de-Broglie
d) Schrodinger

Correct Answer. (d) Schrodinger

Q2. If the momentum of a particle is increased to four times, then the de-Broglie wavelength will become:

a) two times
b) four times
c) half times
d) one-fourth times

Correct Answer. (d) one-fourth times.

Q3. Calculate the wavelength of light with an energy of 5.22×10^{-19} J.

Answer. $E = \frac{hc}{\lambda}$

On rearranging the above equation, the wavelength of light can be calculated as-

$$\lambda = \frac{(6.26 \times 10^{-34} Js)\,(3.0 \times 10^{8} ms^{-1})}{5.22 \times 10^{-19} J} = 3.81 \times 10^{-7} m$$

Λ = 3.81× 10^{-7} m = 381 nm.

Q4. Fill in the blank.

The quantum number that is not associated with the Schrodinger equation is ____.

Answer. Spin quantum number.

Spin quantum number is not associated with the Schrodinger equation because it always shows a value of -½ and +½ .

Q5. How many subshells and orbitals are contained within the principal shell with n = 4?

Answer. We know that l can have any integral value between 0 and n – 1. If n = 4, then l can be 0, 1, 2, or 3. Because the shell has four l values, it has four subshells, each with a different number of orbitals depending on the allowed ml values.

- For l = 0, ml can only be 0, so the l = 0 subshell has one orbital.
- For l = 1, ml can be 0 or 1, resulting in three orbitals in the l = 1 subshell.
- Since ml for l = 2 can be 0, 1, or 2, there are five orbitals in the l = 2 subshell.
- The final allowed value of l is l = 3, for which ml can be 0, ±1, ±2, or ±3, yielding seven orbitals in the l = 3 subshell.

The total number of orbitals in the n = 4 principal shell is equal to n^2 : the sum of the number of orbitals in each subshell.

1 + 3 + 5 + 7 = 16 orbitals = (4 principal shells)^2.