# 3. CONCEPT OF ORBITAL

## SOLUTIONS

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## TEACHING TASK

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### JEE MAIN LEVEL QUESTIONS

1. Which of the following statements about s orbitals is incorrect?

   a) S orbitals are spherical in shape.

   b) S orbitals can hold a maximum of 2 electrons.

   c) S orbitals have a single nodal plane.

   d) S orbitals have higher energy compared to p orbitals.

**Answer:c,d**

Solution: s-orbitals are spherical, so they do not have a nodal plane. They may have spherical nodes (radial nodes) depending on the principal quantum number, but no planar nodes.

s orbitals have LOWER energy than p orbitals of the same principal quantum level (n).

The energy order for orbitals in the same shell is: s < p < d < f

2. Which of the following is not a characteristic of s-orbitals?

   a) They have a spherical shape.

   b) They can have multiple nodal planes.

   c) Electrons in s-orbitals have lower energy compared to electrons in p-orbitals.

   d) S-orbitals are found in all sublevels (e.g., 1s, 2s, 3s, etc.).

**Answer:b**

Solution:s-orbitals do not have nodal planes. They may have radial (spherical) nodes only.

3. In an atom, which of the following statements regarding s-orbitals is correct?

   a) All s-orbitals have the same energy.

   b) The 3s orbital is larger than the 2s orbital.

   c) An s-orbital can hold up to 3 electrons.

   d) S-orbitals are shaped like a figure-eight.

**Answer:b**

Solution:Higher principal quantum number (n) $\rightarrow$ larger orbital size.

4. Which of the following is true about the orientation of p orbitals in space?

a) px, py, and pz orbitals are aligned along the x, y, and z axes, respectively.

b) px, py, and pz orbitals are oriented randomly in space.

c) px and py orbitals lie along the x-axis, while pz lies along the z-axis.

d) px and pz orbitals lie along the x-axis, while py lies along the y-axis.

**Answer:A**

Solution:p-orbitals are mutually perpendicular along x, y, z axes.

5. Which of the following is NOT a correct statement about p-orbitals?

a) They have a dumbbell shape.

b) They can hold a maximum of 8 electrons.

c) They have a principal quantum number of 2.

d) They have a nodal plane perpendicular to the axis of the dumbbell.

**Answer:b**

Solution:Each p-subshell (px, py, pz) holds 2 electrons ? total 6 electrons (not 8).

Correct Facts:Dumbbell shape (a), nodal plane (d), and principal quantum number $n \geq 2$ (c).

6. Which of the following statements is true regarding the orientation of p-orbitals in space?

a) All p-orbitals are aligned along the same axis.

b) P-orbitals are oriented randomly in space.

c) P-orbitals are aligned along the x, y, and z axes.

d) P-orbitals are aligned along the principal quantum number axis.

**Answer:c**

Solution:p-orbitals are directional and fixed along x/y/z axes in Cartesian coordinates.

7. How does the energy of p-orbitals compare to that of s-orbitals in a hydrogen atom?

a) P-orbitals have lower energy than s-orbitals.

b) P-orbitals have higher energy than s-orbitals.

c) P-orbitals have the same energy as s-orbitals.

d) The energy comparison depends on the principal quantum number (n).

**Answer:c**

Solution:In hydrogen (single-electron system), orbitals with the same n are degenerate (same energy).

In multi-electron atoms, p-orbitals are higher in energy than s-orbitals (b).

8. The number of nodal planes in a $p_x$ orbital is

A) one B) two C) three D) four

**Answer:A**

Solution:All p-orbitals have 1 nodal plane (e.g., px has a yz nodal plane).

9. The probability of finding electron in XY plane for $P_Z$ - orbital is

A) 100% B) 50% C) 99.9% D) 0%

**Answer:D**

Solution:The pz orbital's nodal plane is the XY plane . Electron probability is zero there.

10. Which of the following is correct with respect to 'p' orbitals?

A) Spherical B) Strong directional character

C) Five fold degenerate D) No directional character

**Answer:B**

Solution:p-orbitals are directional (unlike spherical s-orbitals).

11. Which of the following is true regarding d-orbitals?

a) They can hold a maximum of 6 electrons.

b) They exhibit spherical symmetry.

c) They have lower energy than s-orbitals.

d) They are found in the first principal energy level.

**Answer:None**

Solution: d-orbitals can hold 10 electrons (5 orbitals × 2 each).

Also:They are not spherical

They start from n = 3, not n = 1.

12. Which of the following statements regarding the shape of d-orbitals is true?

a) All d-orbitals have the same shape.

b) d-orbitals have different shapes but the same energy.

c) d-orbitals have different shapes and different energies.

d) d-orbitals are not real and cannot be described by shape.

**Answer:b**

Solution:All 5 d-orbitals have different orientations and shapes, but are degenerate (same energy) in a free atom.

13. Which of the following d orbitals has a diagonal nodal plane ?

A) $d_{xy}$ B) $d_{yz}$ C) $d_{zx}$ D) $d_{x^2-y^2}$

**Answer:D**

Solution: $d_{x^2-y^2}$ has nodal planes at 45° to the x/y axes.

14. Which of the following 3d orbitals has electron density in all three axes ?

A) $3d_{xy}$ B) $3d_{yz}$ C) $3d_{z^2}$ D) $3d_{zx}$

**Answer:C**

Solution:The $d_{z^2}$ orbital has a doughnut-shaped electron density around the z-axis and lobes along it. Electron density spreads over all three axes more uniformly compared to others.

15. The maximum number of electrons accommodated in 5f orbitals

A) 5 B) 10 C) 14 D) 18

**Answer:C**

Solution:5f subshell has 7 orbitals, each can hold 2 electrons $\rightarrow$ 7 × 2 = 14 electrons.

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## JEE ADVANCED LEVEL

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**MULTI CORRECT ANSWER TYPE**

1. Which of the following is true regarding the orientation of p orbitals?

a) Px, Py, and Pz orbitals are oriented along the x, y, and z axes respectively.

b) Px, Py, and Pz orbitals are all oriented in the same direction.

c) Px and Py orbitals are perpendicular to each other.

d) P orbitals are spherically symmetric.

**Answer:A,C**

Solution:Option (a): Correct. The three p-orbitals (px, py, pz) are aligned along the x, y, and z axes respectively.

Option (c): Correct. Px and Py are mutually perpendicular (90° to each other).

Option (b): Incorrect. All three p-orbitals are not oriented in the same direction.

Option (d): Incorrect. P-orbitals are dumbbell-shaped, not spherically symmetric (s-orbitals are spherical).

2. Which of the following statements about d orbitals are true?

a) There are five d orbitals in each principal energy level.

b) The shape of d orbitals is spherical.

c) d orbitals have angular nodes.

d) The maximum number of electrons that can occupy a single d orbital is 4.

**Answer:a,c**

Solution:Option (a): Correct. There are 5 d-orbitals (dxy, dxz, dyz, $dx^2-y^2$, $dz^2$) for each energy level where they exist ($n \geq 3$).

Option (c): Correct. d-orbitals have angular nodes (nodal planes). The number of angular nodes = azimuthal quantum number ($l = 2$ for d-orbitals).

Option (b): Incorrect. d-orbitals are not spherical (they have cloverleaf/dumbbell shapes).

Option (d): Incorrect. A single d-orbital can hold max 2 electrons (not 4). The entire d-subshell (5 orbitals) can hold 10 electrons.

3. Regarding the shapes of d orbitals, which of the following statements are correct?

a) All d orbitals have the same shape.

b) The shape of a d orbital depends on its principal quantum number.

c) The shapes of d orbitals include dumbbell-shaped and clover leaf-shaped.

d) The orientation of d orbitals is fixed along the x, y, and z axes.

**Answer:c,d**

Solution:(a) Incorrect — They have different orientations and patterns, like cloverleaf (dxy, dxz, dyz) and donut-lobed ($dz^2$)

(b) Incorrect — Shape is determined by the azimuthal quantum number ($l = 2$), not by principal quantum number (n). Size depends on n, not shape.

(c) Correct — d orbitals include cloverleaf-shaped (like dxy, dxz) and $dz^2$, which looks like a dumbbell with a torus.

(d) Correct — Each d orbital has a specific orientation involving axes, such as dxy, dxz, dyz, etc.

**REASON AND ASSERTION TYPE**

4. Assertion: The lobes of a p-orbital have the same size and shape.

Reason: P-orbitals have symmetric lobes with the same electron density.

**Answer:A**

Solution:p-orbitals (px, py, pz) consist of two identical lobes (same size/shape) with equal electron density but opposite phases.

The symmetry in lobes arises from the wavefunction's mathematical form (R explains A).

5. Assertion: The angular momentum quantum number (l) determines the shape of an orbital.

   Reason: Orbitals with different values of the angular momentum quantum number have different shapes.

**Answer:A**

Solution:l = 0 (s-orbital): Spherical

l = 1 (p-orbital): Dumbbell

l = 2 (d-orbital): Cloverleaf/dumbbell

Thus, l directly governs orbital shape (R justifies A).

6. Assertion: The lobes of a p-orbital are arranged symmetrically around the nucleus.

   Reason: P-orbitals have two lobes of electron density oriented in opposite directions.



**Answer:A**

Solution:p-orbitals are bilobed with lobes of equal size but opposite phase (e.g., + and - regions).

The symmetry arises from their directional nature (R explains A).

7. Assertion: All d-orbitals have the same shape.

   Reason: D-orbitals exhibit five distinct shapes, each with a different orientation in space.

**Answer:D**

Solution:A is false: d-orbitals have different shapes (e.g., $dz^2$ has a unique "dumbbell + torus" shape).

R is true: There are 5 distinct d-orbitals (dxy, dxz, dyz, $dx^2$-$y^2$, $dz^2$) with different orientations.

8. Assertion: The number of lobes in an s-orbital is always one.

   Reason: The s-orbital is spherical and has a single lobe of electron density.

**Answer:A**

Solution:s-orbitals are single-lobed and spherically symmetric (no angular nodes).

Higher s-orbitals (e.g., 2s, 3s) have radial nodes, but still only one lobe overall (R explains A).

9. Assertion: The shapes of orbitals determine the spatial distribution of electrons in an atom.

   Reason: Electrons are most likely to be found in regions of space where the probability density of the orbital is highest.

**Answer:A**

Solution:Orbital shape = region where $|\psi^2|$ (probability density) is significant.

Electrons occupy these high-probability regions (R directly explains A).

10. Assertion: The number of d-orbitals in a given shell is equal to the principal quantum number (n) minus one.

    Reason: Each d subshell contains five orbitals, regardless of the principal quantum number.

**Answer:D**

Solution:A is false: The number of d-orbitals is always 5 (for any $n \geq 3$), not n-1.

R is true: All d-subshells (3d, 4d, etc.) contain 5 orbitals.

11. Assertion: The shapes of d-orbitals are more complex than those of s and p-orbitals.

    Reason: D-orbitals have multiple lobes and angular nodes, giving them a more intricate shape.

**Answer:A**

Solution:d-orbitals have 4 lobes (cloverleaf) or dumbbell + torus ($dz^2$), while s/p are simpler.

Their complexity stems from higher angular nodes (l = 2) (R explains A).

12. Assertion: The orientation of an s-orbital is fixed in space.

    Reason: The s-orbital is spherically symmetric and has no directional preference.

**Answer:D**

Solution:A is false: s-orbitals are non-directional (no fixed orientation).

R is true: Spherical symmetry means no preferred direction (R contradicts A).

13. Assertion: All orbitals with the same principal quantum number (n) have the same shape.

    Reason: Orbitals with the same principal quantum number but different angular momentum quantum numbers have different shapes.

**Answer:D**

Solution:A is false: For a given n, orbitals can be s (spherical), p (dumbbell), d (clover-

leaf), etc.

R is true: Shape depends on l (not n), so s/p/d differ even if n is the same.

**STATEMENT TYPE**

A) Both (STATEMENT-1 ) and (STATEMENT-II ) are true

B) Both (STATEMENT) and (STATEMENT-II) are false

C) (STATEMENT-I) is true but (STATEMENT-II) is false

D) (STATEMENT-I) is false but (STATEMENT-II) is true

14. **Statement-I :** Nodal plane of $p_x$ atomic orbital is yz plane.

**Statement-II :** In $p_x$ atomic orbital electron density is zero in the yz plane.

**Answer:A**

Solution:Statement-I: The px orbital has its nodal plane in the yz-plane (where ?=0).

Statement-II: Since the yz-plane is the nodal plane for px, the electron density ($|\psi|^2$) is indeed zero there.

Connection: Statement-II directly supports Statement-I.

15. **Statement-I :** There are two spherical nodes in 3s-orbital.

**Statement-II :** There is no angular node in 3s-orbital.

**Answer:A**

Solution:Statement-I: For 3s (l=0):

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

Statement-II: s-orbitals (l=0) have no angular nodes (nodal planes).

Note: The statements are independent but both correct.

16. **Statement I:** P-orbital can accomadate 6 electrons

**Statement II:** P-subshell has 3 orbitals

**Answer:D**

Solution:Statement-I: A single p-orbital (e.g., px, py, or pz) holds max 2 electrons (not 6).

Statement-II: The p-subshell consists of 3 orbitals (px, py, pz), which together can hold 6 electrons

## COMPREHENSION TYPE

### Comprehension-I

d-Orbitals: d-orbitals have more complex shapes compared to s and p orbitals. There are five d-orbitals: $d_{xy,}$ $d_{yz,}$ $d_{zx,}$ $d_{X^2-Y^2}$ and $d_z^2$. The $d_z^2$ orbital has a doughnut shape with a ring along the z-axis and a spherical node at the nucleus. The $d_{xy,}$ $d_{yz,}$ $d_{zx,}$ orbitals have four lobes and are oriented between the axes. The $d_{X^2-Y^2}$ orbital has four lobes but lies along the axes.

17. Which orbital(s) have lobes oriented between the axes?

a) $d_{xy,}$ $d_{yz,}$ $d_{zx,}$ b) $d_z^2$ c) $d_{X^2-Y^2}$ d) Both B & C

**Answer:a**

Solution:The $d_{xy,}$ $d_{yz,}$ $d_{zx,}$ orbitals have four lobes and are oriented between the axes.

18. In which set of orbitals does the azimuthal quantum number, l, have a value of 2?

A) s-orbitals B) p-orbitals C) d-orbitals D) f-orbitals

**Answer:C**

Solution:The azimuthal quantum number (l) determines the orbital shape:

l=0 $\rightarrow$ s-orbitals

l=1 $\rightarrow$ p-orbitals

l=2 $\rightarrow$ d-orbitals (given in the comprehension).

l=3 $\rightarrow$ f-orbitals

### Comprehension-II

Shape of the orbitals are related to the solutions of Schrodinger wave equation, and gives the space in which the probability of finding an electron is maximum.

19. Consider the following statements :

A) Electron density in the XY plane in $3d_{x^2-y^2}$ orbital is zero

B) Electron density in the XY plane in $3d_{z^2}$ orbital is zero.

C) 2s orbital has one nodal surface D) for $2p_z$ orbital, YZ is the nodal plane.

Which of these are incorrect statements :

A) a & c B) b & c C) Only b D) a, b, d

**Answer:D**

Solution:A)Incorrect –The $3d_{x^2-y^2}$ orbital lies in the XY plane, with lobes along the x- and y-axes.So, electron density is maximum in the XY plane, not zero.

B) Incorrect –The $3d_{z^2}$ orbital has a donut-shaped ring (toroid) of electron density in the XY plane.So, electron density is not zero in XY plane — it's significant.

C) Correct –Radial nodes = n – l – 1 = 2 – 0 – 1 = 1 radial node (spherical nodal surface)

D) Incorrect –The $2p_z$ orbital lies along the z-axis, so its nodal plane is the XY plane, not YZ.

**INTEGER TYPE**

20. p-subshell have _____ orbitals

**Answer:3**

Solution:The p-subshell consists of three orbitals:$p_x$,$p_y$, and $p_z$.

Each orbital can hold 2 electrons, so the entire p-subshell accommodates 6 electrons.

21. How many nodes does a d-orbital have?

**Answer:2**

Solution:Total nodes = Radial nodes + Angular nodes.

For a d-orbital (l=2):

Angular nodes (nodal planes) = l=2.

Radial nodes = n-l-1.

Example: For 3d, radial nodes = 3-2-1=0.

Conclusion: All d-orbitals have 2 angular nodes, but radial nodes depend on n.

22. For s-orbital number of nodal planes = _____

**Answer:0**

Solution:s-orbitals (l=0) are spherically symmetric and have:

No angular nodes (nodal planes) because l=0.

**MATCHING TYPE**

23.**Answer:A-C,B-B,C-A,D-D**

Solution:

| **List - I** | **List - II** |
|---|---|
| A) s-orbital | C) $2e^-$ |
| B) P-orbital | B) $6e^-$ |
| C) d-orbital | A) $10e^-$ |

D) f- orbital D) $14e^-$

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## LEARNERS TASK

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### CONCEPTUAL UNDERSTANDING QUESTIONS (CUQ'S)

1. Shape of d-orbital is

A) dumbbell B) double dumbell C) spherical D) axial

**Answer:B**

Solution:d-orbitals have four lobes (cloverleaf shape) or a dumbbell + torus ($d_{z^2}$).

Often described as "double dumbbell" due to their complex geometry.

2. For the d-orbital

A) $\ell = 3$ B) $\ell = 1$ C) $\ell = 2$ D) $\ell = 0$

**Answer:C**

Solution:l=2 $\rightarrow$ d

3. For 2p-orbital

A) n=1 B)n=2 C)n=3 D)n=4

**Answer:B**

Solution:The number 2 in 2p indicates n=2.

4. Shape of p-orbital is

A) sharp B) principal C) dumbbell D) all direction

**Answer:C**

Solution:p-orbitals ($P_x$ ,$p_y$,$p_z$ ) have two lobes (dumbbell shape) with a nodal plane at the nucleus.

5. Shape of $d_{z2}$ is

A)doughnat B) bady soother type C) both D) dumbbell

**Answer:C**

Solution: $d_{z2}$ has a dumbbell along the z-axis and a doughnut-shaped ring in the XY plane.

6. The value of $m_1$ for $P_y$

A) $\pm 1$ B)0 C) $\pm 2$ D)none

**Answer:D**

Solution:For $p_y$, $m_1$ can be ±1 (varies by convention). No single fixed value.

7. The value of 'l' for s orbital

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

**Answer:B**

Solution:s-orbitals have l=0 (spherical symmetry).

8. Which orbital shape is characterized by having a spherical probability distribution?

a) s b) p c) d d) f

**Answer:a**

Solution:Only s-orbitals are spherically symmetric.

9. How many orbitals are present in an f subshell?

a) 1 b) 3 c) 5 d) 7

**Answer:d**

Solution:f-subshell has 7 orbitals

10. Which sublevel(s) have azimuthal quantum number (l) values of 0?

a) s b) p c) d d) f

**Answer:a**

Solution:Only s-subshell has l=0.

## JEE MAIN LEVEL QUESTIONS

1. Which statement best describes the probability distribution of finding an electron in an s-orbital?

a) It is concentrated in a single plane.

b) It is concentrated along the axis.

c) It is spherically symmetrical around the nucleus.

d) It is highly directional.

**Answer:c**

Solution: An s-orbital has no angular dependence—its wavefunction depends only on distance from the nucleus—so the electron cloud is a perfect sphere.

2. Which of the following is true about the shapes of p-orbitals?

a) They are symmetrical about all axes

b) They are symmetrical about one axis only

c) They are asymmetrical about all axes

d) They are symmetrical about two axes only

**Answer:b**

Solution: Each p-orbital (px, py or pz) is oriented along a single Cartesian axis and is symmetric under rotation around that axis, but not symmetric in the other two directions.

3. Which of the following is true about p-orbitals?

a) They have spherical shape

b) They can hold a maximum of 4 electrons

c) They have three mutually perpendicular dumbbell-shaped lobes

d) They are named as spherically symmetrical orbitals

**Answer:c**

Solution:The p-subshell consists of three orbitals ($p_x$, $p_y$, $p_z$), each of which is a two-lobed "dumbbell," and the three are oriented at right angles to one another.

4. Which of the following statements is true about the shape of d-orbitals?

a) All d-orbitals have the same shape. b) $d_{xy}$ and $d_{x^2-y^2}$ have similar shapes.

c) $d_{z^2}$ has a lobed shape. d) d-orbitals are spherical in shape.

**Answer:c**

Solution:(a) False: d-orbitals have different shapes (e.g., $d_{z^2}$ is unique with a "dumbbell + doughnut" shape).

(b) False: $d_{xy}$ and $d_{x^2-y^2}$ have different orientations (cloverleaf vs. axial lobes).

(c) True: $d_{z^2}$ has two lobes along the z-axis and a doughnut in the XY plane.

(d) False: Only s-orbitals are spherical.

5. What is the maximum number of electrons that can occupy a single s-orbital?

A) 1 B) 2 C) 4 D) 6

**Answer:B**

Solution:Any single orbital (s, p, d, or f) can hold max 2 electrons (Pauli exclusion principle).

6. The radial distribution curve of 2s sublevel consists of x nodes, x is :

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

**Answer:A**

Solution:Radial nodes = n-l-1.

For 2s (n=2, l=0):2-0-1=1 radial node.

7. 3py orbital has.....nodal plane :

A) XY 2 YZ C) ZX D) All of these

**Answer:C**

Solution:For py, the nodal plane is the ZX-plane

8. The maximum radial probability in 1s-orbital occurs at a distance when [ $r_0$ = Bohr radius ]

A) $r = r_0$ B) $r = 2r_0$ C) $r = \frac{r_0}{2}$ D) $2r = \frac{r_0}{2}$

**Answer:A**

Solution:For 1s, the peak electron density occurs at r=$a_0$(Bohr radius, ~0.529 Å)

9. The maximum probability of finding electron in the $d_{xy}$ orbital is:

A) Along the x-axis B) Along the y-axis

C) At an angle of $45^0$ from the x and y axis

D) At an angle of $90^0$ from the x and y axis.

**Answer:C**

Solution: $d_{xy}$ has four lobes oriented between the axes (45° from x and y).

10. The hydrogen-like species $Li^{2+}$ is in a spherically symmetric state $S_1$ with one radial node. Upon absorbing light the ion undergoes transition to a state $S_2$. The state $S_2$ has one radial node and its energy is equal to the ground state energy of the hydrogen atom.

The state $S_1$ is : **[JEE 2010]**

A) 1s B) 2s C) 2p D) 3s

**Answer:B**

Solution:Spherically symmetric states are s-orbitals (since p,d,f orbitals are not spherically symmetric).

Radial nodes formula:Number of radial nodes=n-l-1

For s-orbitals (l=0), radial nodes =n-1.

Given: 1 radial node ?

n-1=1 ?

n=2.

The state is 2s.

11. Energy of the state $S_1$ in units of the hydrogen atom ground state energy is : **[JEE 2010]**

A) 0.75 B) 1.50 C) 2.25 D) 4.50

**Answer:C**

Solution:Energy formula for hydrogen-like atoms: $E_n = -13.6(\frac{Z^2}{n^2})eV$

For $Li^{2+}$ (Z=3) in$S_1$=2s state (n=2): $E_2 = -13.6(\frac{3^2}{2^2})eV = -30.6eV$

Ratio to hydrogen ground state energy (-13.6eV):

$$\frac{|E_2|}{|E_{1,H}|} = \frac{30.6}{13.6} = 2.25$$

12. The orbital angular momentum quantum number of the state $S_2$ is : **[JEE 2010]**

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

**Answer:B**

Solution:Given about $S_2$ Energy = Hydrogen ground state energy (-13.6eV)

$E_{S_2} = -13.6eV$

For $Li^{2+}$ (Z=3), energy formula: $E_n = -13.6(\frac{9}{n^2})eV$

To match -13.6eV:

$-13.6eV = -13.6(\frac{9}{n^2})eV$

$n = 3$

$S_2$ is the n=3 state.

Radial nodes condition for $S_2$

Radial nodes=n-l-1=1

For n=3: 3-l-1=1

l=1 (p-orbital).

13. The angular wave function of which orbital will not disturb by the variation with azimuthal angle only

A) 1s and 2s B) $2p_z$ and $2d_z^2$ C) $2p_x$ and $3d_z^2$ D) $2p_x$ and 2s

**Answer:A**

Solution:To solve the question regarding which orbital's angular wave function is not disturbed by the variation with the azimuthal angle, we can follow these steps:

Step 1: Understand the Angular Wave Function

The angular wave function describes how the probability density of finding an electron varies with angles in three-dimensional space. It is typically expressed in terms of spherical coordinates, which include the polar angle ($\theta$) and the azimuthal angle ($\psi$).

Step 2: Identify the Orbitals

The main types of orbitals are s, p, d, and f:

- s orbitals: These are spherical and have no angular dependence. Their wave function depends only on the radial distance (r).

- p orbitals: These have a dumbbell shape and depend on both r and $\theta$.

- d orbitals: These have more complex shapes and also depend on both r and ?.

- f orbitals: These are even more complex and depend on r, $\theta$, and $\psi$.

Step 3: Analyze the s Orbital

The s orbital is unique because it is spherical. This means that the electron density is uniform in all directions, and it does not change with variations in the azimuthal angle ($\psi$). Therefore, the angular wave function for the s orbital does not depend on $\psi$.

14. $d_{z^2}$ – orbital has :

A) Two lobes along z-axis and a ring along xy-plane

B) Two lobes along z-axis and two lobes along xy-plane

C) Two lobes along z-axis and a ring along yz-plane

D) Two lobes and a ring along z-axis

**Answer:A**

Solution: $d_{z^2}$ – orbital consists of:

Two lobes along the z-axis (one positive and one negative phase).

A torus (doughnut-shaped ring) in the xy-plane (centered around the nucleus).

15. Which of the following orbitals has a dumbbell shape?

a) $3d_{z^2}$ b) $3d_{x^2-y^2}$ c) $3d_{xz}$ d) $3d_{yz}$

**Answer:c,d**

| Solution: | Orbital | Shape |
|---|---|---|
| | 3dxz | Dumbbell between x and z axes |
| | 3dyz | Dumbbell between y and z axe |
| | $3dx^2–y^2$ | Cloverleaf in x–y plane |

$3dz^2$Unique: Dumbbell with a doughnut (torus) around the middle (not pure dumbbell)

10. In case of $d_{x^2-y^2}$ orbital

A) Probability of finding the electron along x-axis is zero.

B) Probability of finding the electron along y-axis is zero.

C) Probability of finding the electron is maximum along x and y-axis.

D) Probability of finding the electron is zero in x-y plane

**Answer:C**

Solution:The $d_{x^2-y^2}$ orbital has four lobes—two along the +x and –x axes and two along the +y and –y axes.

Electron probability is highest along the x and y-axes (where the lobes are concentrated).

Probability is zero in the planes at 45° between the x and y-axes (nodal planes).

## JEE ADVANCED LEVEL

### MULTI CORRECT ANSWER TYPE

1. Which of the following statements about p orbitals are true?

a) They have a dumbbell shape. b) They can hold a maximum of 2 electrons.

c) They have a principal quantum number of 1.

d) They are spherical in shape.

**Answer:a,b**

Solution:a) Correct – p orbitals have a dumbbell shape with two lobes.

b) Correct – Each p orbital can hold 2 electrons (one with spin-up, one with spin-down).

c) Incorrect – p orbitals do not have a fixed principal quantum number ($n \geq 2$ for p orbitals; n=1 only has s orbitals).

d) Incorrect – p orbitals are not spherical (s orbitals are spherical).

2. Which of the following is true regarding the energy of p orbitals?

a) The energy of a p orbital decreases with increasing principal quantum number.

b) The energy of a p orbital increases with increasing principal quantum number.

c) The energy of a p orbital depends only on its azimuthal quantum number.

d) The energy of a p orbital is the same for all atoms.

**Answer:b**

Solution:a) Incorrect – Energy increases (not decreases) as the principal quantum number (n) increases (e.g., 2p < 3p < 4p).

b) Correct – Higher principal quantum numbers mean higher energy (less tightly bound to the nucleus).

c) Incorrect – Energy depends on both principal (n) and azimuthal (l) quantum numbers, not just l.

d) Incorrect – Energy varies across atoms due to nuclear charge and electron shielding.

**REASON AND ASSERTION TYPE**

A) Both (A) and (R) are true and (R) is the correct explanation of(A)

B) Both (A) and (R) are ture and (R) is not the correct explanation of (A)

C) (A) is true but (R) is false D) (A) is false but (R) is true

3. Assertion: The shape of an s-orbital is spherical.

Reason: The s-orbital has only one orientation in space.

**Answer:A**

Solution:(A) is true – s-orbitals are spherical in shape.

(R) is true – s-orbitals have no preferred orientation (only one possible shape).

(R) explains (A) – Since s-orbitals have no angular dependence, they must be spherically symmetric.

4. Assertion: S-orbitals are spherical in shape.

Reason: S-orbitals have no angular nodes.

**Answer:A**

Solution:(A) is true – s-orbitals are spherical.

(R) is true – s-orbitals have no angular nodes (only radial nodes).

(R) explains (A) – The absence of angular nodes means the electron density is uniform in all directions, leading to a spherical shape.

5. Assertion: P-orbitals have a dumbbell shape.

Reason: P-orbitals have two lobes of electron density with a node at the nucleus.

**Answer:A**

Solution:(A) is true – p-orbitals are dumbbell-shaped.

(R) is true – p-orbitals consist of two lobes separated by a nodal plane (where electron density is zero).

(R) explains (A) – The presence of two lobes with a central node results in the dumbbell shape.

6. Assertion: The number of p-orbitals in a given shell is equal to the principal

quantum number (n) minus one.

Reason: Each p subshell contains three orbitals, regardless of the principal quantum number.

**Answer:D**

Solution:(A) is false – The number of p-orbitals does not depend on n; it is always 3 (px, py, pz).

(R) is true – Every p subshell has three orbitals, irrespective of the principal quantum number.

7. Assertion: P-orbitals can have orientations along the x, y, and z axes.

Reason: P-orbitals have three distinct orientations perpendicular to each other.

**Answer:A**

Solution:(A) is true – p-orbitals are oriented along x, y, and z axes.

(R) is true – The three p-orbitals are mutually perpendicular (90° to each other).

(R) explains (A) – The three orientations correspond to the x, y, and z directions.

8. Assertion: D-orbitals have a complex shape with multiple lobes.

Reason: D-orbitals have five distinct orientations and exhibit varying lobes of electron density.

**Answer:A**

Solution:(A) is true – d-orbitals have complex shapes (e.g., cloverleaf for $d_{xy}$, $d_{xz}$, $d_{yz}$; dumbbell with a ring for $d_{z^2}$).

(R) is true – There are five d-orbitals with different orientations and multiple lobes.

(R) explains (A) – The different orientations and nodal planes lead to varied lobe structures.

**STATEMENT TYPE**

A) Both (STATEMENT-I ) and (STATEMENT-II ) are true

B) Both (STATEMENT-I ) and (STATEMENT-II) are false

C) (STATEMENT-I) is true but (STATEMENT-II) is false

D) (STATEMENT-I) is false but (STATEMENT-II) is true

9. **Statement-I :** p-orbital has dumb-bell shape.

**Statement-II :** Electrons present in p-orbital can have one of three values for 'm', i.e. 0, +1, –1

**Answer:A**

Solution:Statement-I is true – p-orbitals are dumbbell-shaped with two lobes.

Statement-II is true – The magnetic quantum number (m) for p-orbitals can be –1, 0, or +1, corresponding to the three orientations ($p_x$, $p_y$, $p_z$).

10. **Statement-I :** The $P_x$ orbital has maximum electron density along the x axis and its nodal plane is yz plane

**Statement-II :** For a given atom, for all values of n, the p-orbitals have the same 1shape, but the overall size increase as n increases

**Answer:A**

Solution:Statement-I is true – This describes the $p_x$ orbital, which has:

Maximum electron density along the x-axis.

Nodal plane at yz-plane (where electron density is zero).

Statement-II is true – All p-orbitals (2p, 3p, 4p, etc.) have the same dumbbell shape, but their size increases with principal quantum number (n) due to higher energy levels.

**COMPREHENSION TYPE**

**Comprehension-I**

11. Which orbital type is characterized by its complex shape and can hold up to fourteen electrons?

a) s b) d c) p d) f

**Answer:d**

Solution:The f-orbitals have the most complex shapes (e.g., multi-lobed, flower-like structures).

They can hold a maximum of 14 electrons (7 orbitals × 2 electrons each).

Other orbitals:s: Spherical, holds 2 electrons.

p: Dumbbell-shaped, holds 6 electrons.

d: Cloverleaf/dumbbell with nodes, holds 10 electrons.

12. How do electrons fill orbitals according to quantum mechanics?

a) Randomly b) Starting from the highest energy level

c) Filling lower energy orbitals first d) Filling only the f orbitals first

**Answer:C**

Solution:Electrons follow the Aufbau principle, which states:

Lower energy orbitals are filled first before higher ones.

Example: 1s $\rightarrow$ 2s $\rightarrow$ 2p $\rightarrow$ 3s $\rightarrow$ 3p $\rightarrow$ 4s $\rightarrow$ 3d, etc.

**Comprehension-II**

According to sommerfeld electron revolve around the nucleus in the Elliptical Orbits.Circular orbit is a special case of elliptical orbit when the length of major axis becomes equal to the length of minor axis then the shape of orbit will be circular.

13. For $n^{th}$ Orbit :

A) Number of elliptical path = (n – 1) B) Number of elliptical path = n

C) Number of elliptical path = (n – B) D) Number of elliptical path = n-3

**Answer:A**

Solution:For each value of n, the azimuthal quantum number l can take values from 0 to n – 1.

Each unique value of l corresponds to a different shape (eccentricity) of the orbit:

l = 0 $\rightarrow$ circular orbit (special case)

l = 1 to n – 1 $\rightarrow$ elliptical orbits

**INTEGER TYPE**

14. $d_{z^2}$ _____ lobes

**Answer:2**

Solution:The $dz^2$ orbital has a unique shape:

It consists of 2 lobes along the z-axis (like a dumbbell),

And a doughnut-shaped ring (toroidal lobe) in the xy-plane around the nucleus

15. leaf like or Complex shaped subshell can fill a maxium of _____ electrons

**Answer:14**

Solution:f-subshell has the most complex shapes ("leaf-like") and can hold 14 electrons (7 orbitals × 2 electrons each).

Other subshells:s $\rightarrow$ 2 $e^-$ (spherical).

p $\rightarrow$ 6 $e^-$ (dumbbell).

d $\rightarrow$ 10 $e^-$ (cloverleaf).

**MATRIX MATCHING TYPE**

7. **Answer:A-D,B-C,C-B,D-A**

**Solution:**

| **List - I** | **List - II** |
|---|---|
| A) s-orbital | D) spherical |
| B) P-orbital | C) dumbbell |
| C) d-orbital | B) double dumbbell |
| D) f- orbital | A) complex |

# KEY

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | TEACHING TASK | | | | | |
| | | | JEE MAIN LEVEL QUESTIONS | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| C,D | B | B | A | B | C | C | A | D | B |
| 11 | 12 | 13 | 14 | 15 | | | | | |
| NONE | B | D | C | C | | | | | |
| | | | JEE ADVANCED LEVEL | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| A,C | A,C | C,D | A | A | A | D | A | A | D |
| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| A | D | D | A | A | D | A | C | D | 3 |
| 21 | 22 | 23 | | | | | | | |
| 2 | 0 | A-C,B-B,C-A,D-D | | | | | | | |
| | | | | LEARNERS TASK | | | | | |
| | | | CONCEPTUAL UNDERSTANDING QUESTIONS (CUQ'S) | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| B | C | B | C | C | D | B | A | D | A |
| | | | JEE MAIN LEVEL QUESTIONS | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| C | B | C | C | B | A | C | A | C | B |
| 11 | 12 | 13 | 14 | 15 | 16 | | | | |
| C | B | A | A | C,D | C | | | | |
| | | | JEE ADVANCED LEVEL | | | | | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| A,B | B | A | A | A | D | A | A | A | A |
| 11 | 12 | 13 | 14 | 15 | 16 | | | | |
| D | C | A | 2 | 14 | A-D,B-C,C-B,D-A | | | | |