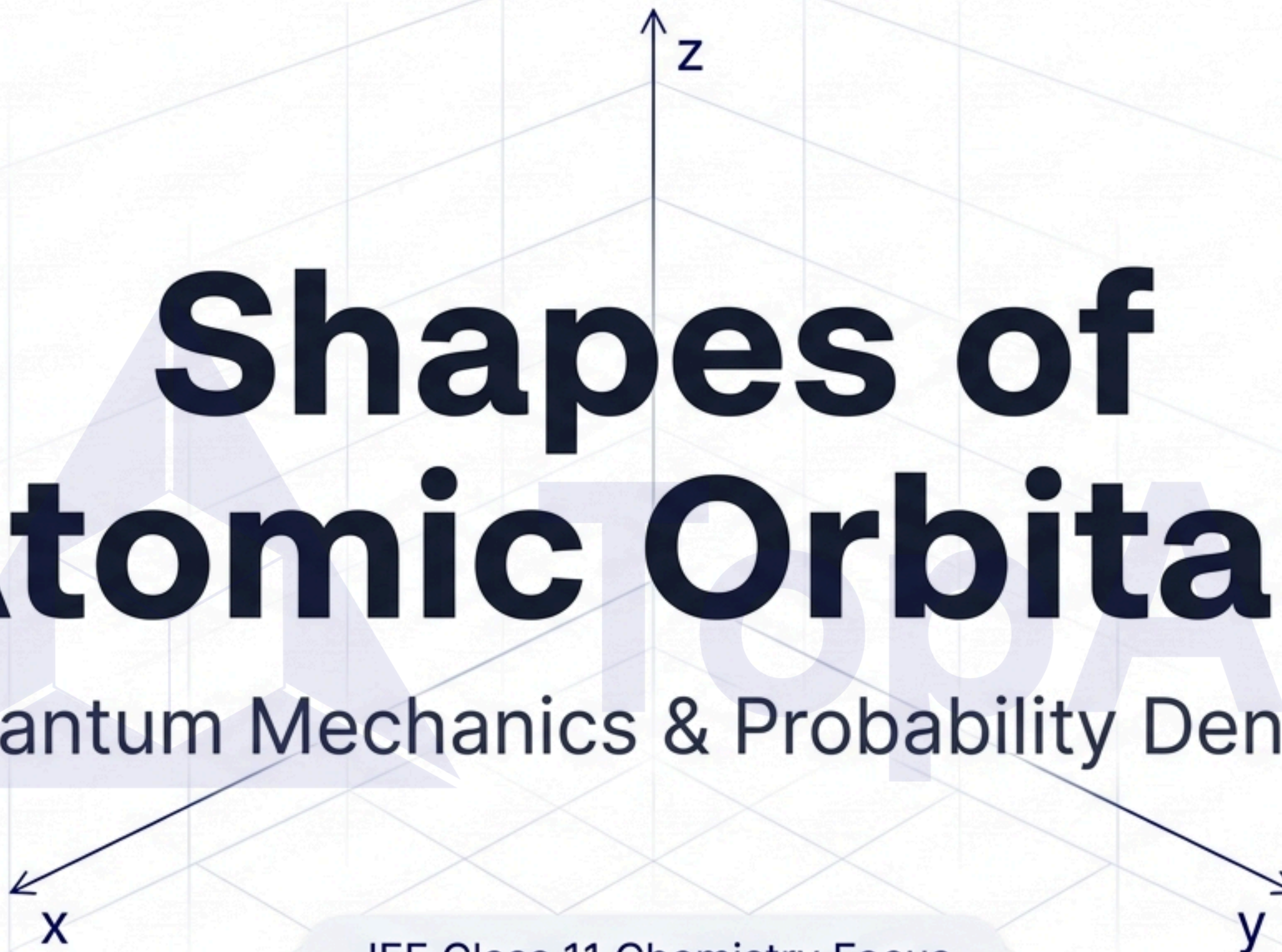
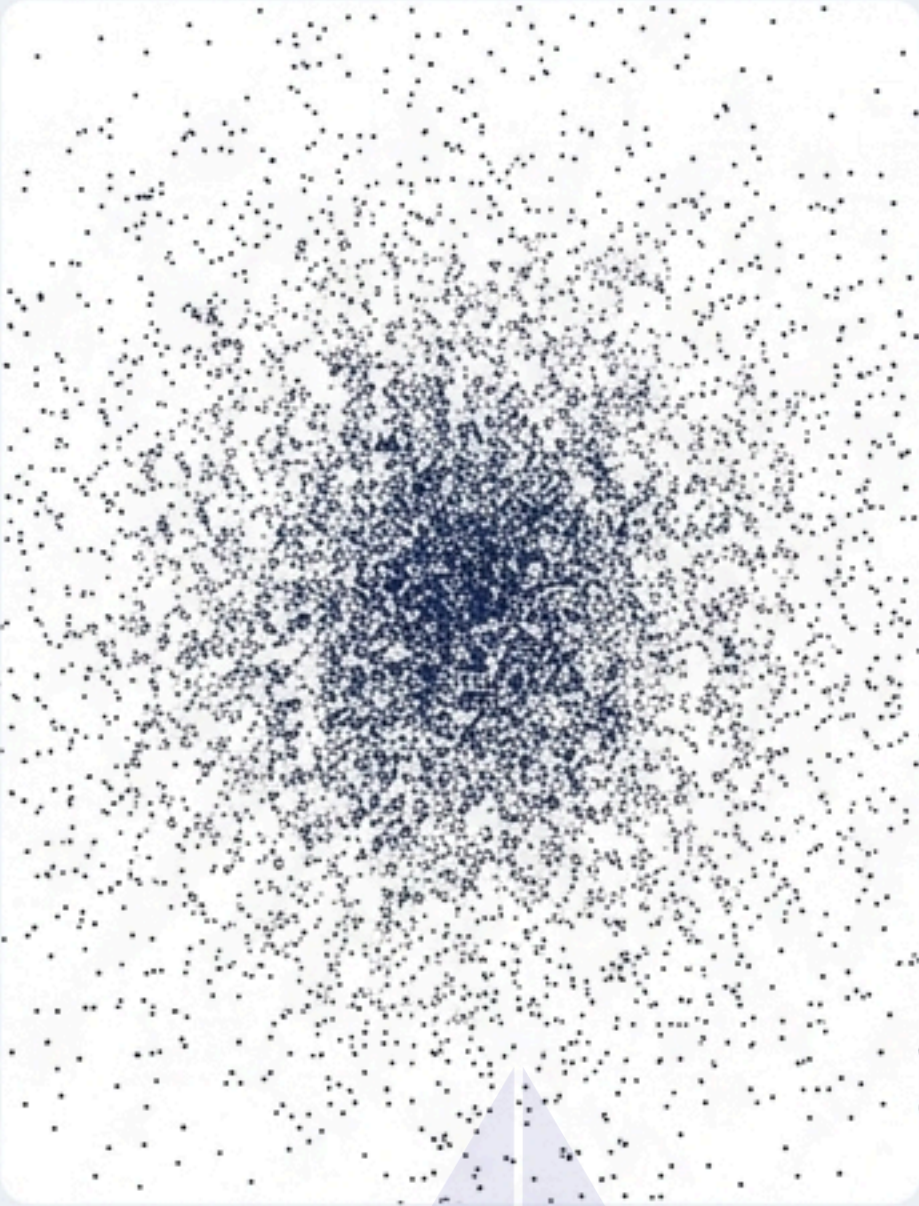


Shapes of Atomic Orbitals

Quantum Mechanics & Probability Density



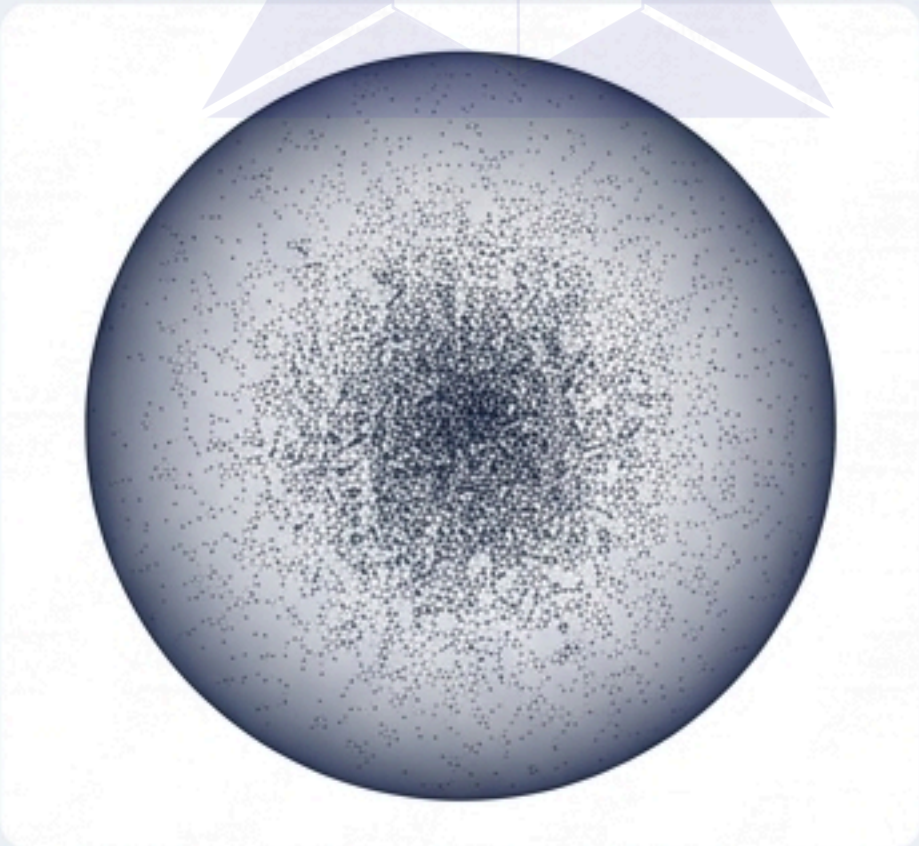
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Probability Density

$$|\psi|^2$$

We cannot pinpoint an electron's exact location, only the probability of finding it in a specific volume.



Boundary Surface Diagram

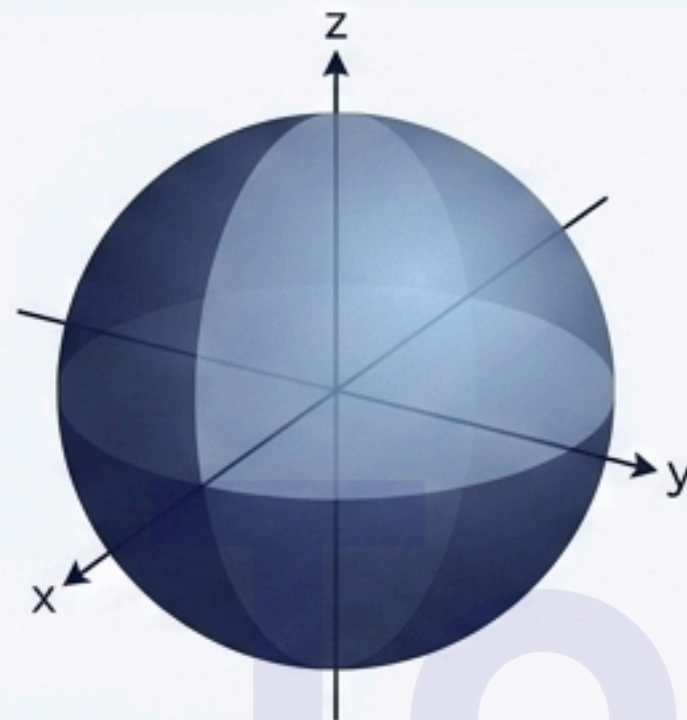
A mathematical envelope enclosing the region where the probability of finding an electron is very high (~90%).



Exam Trap: The probability of finding an electron is never exactly 100% at any finite distance from the nucleus.

The s-Orbital

Shape:
Spherical

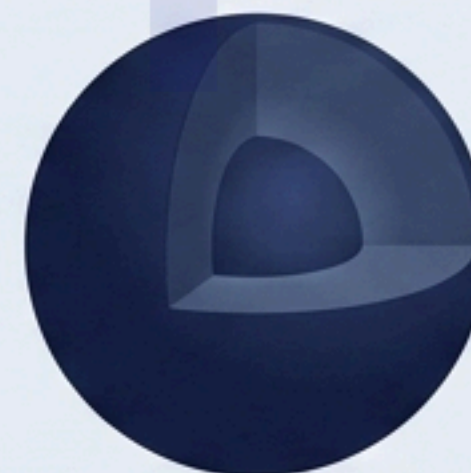


Quantum Code:
 $l = 0$

Rule:
Spherically symmetric (equal probability in all directions from the nucleus).



1s

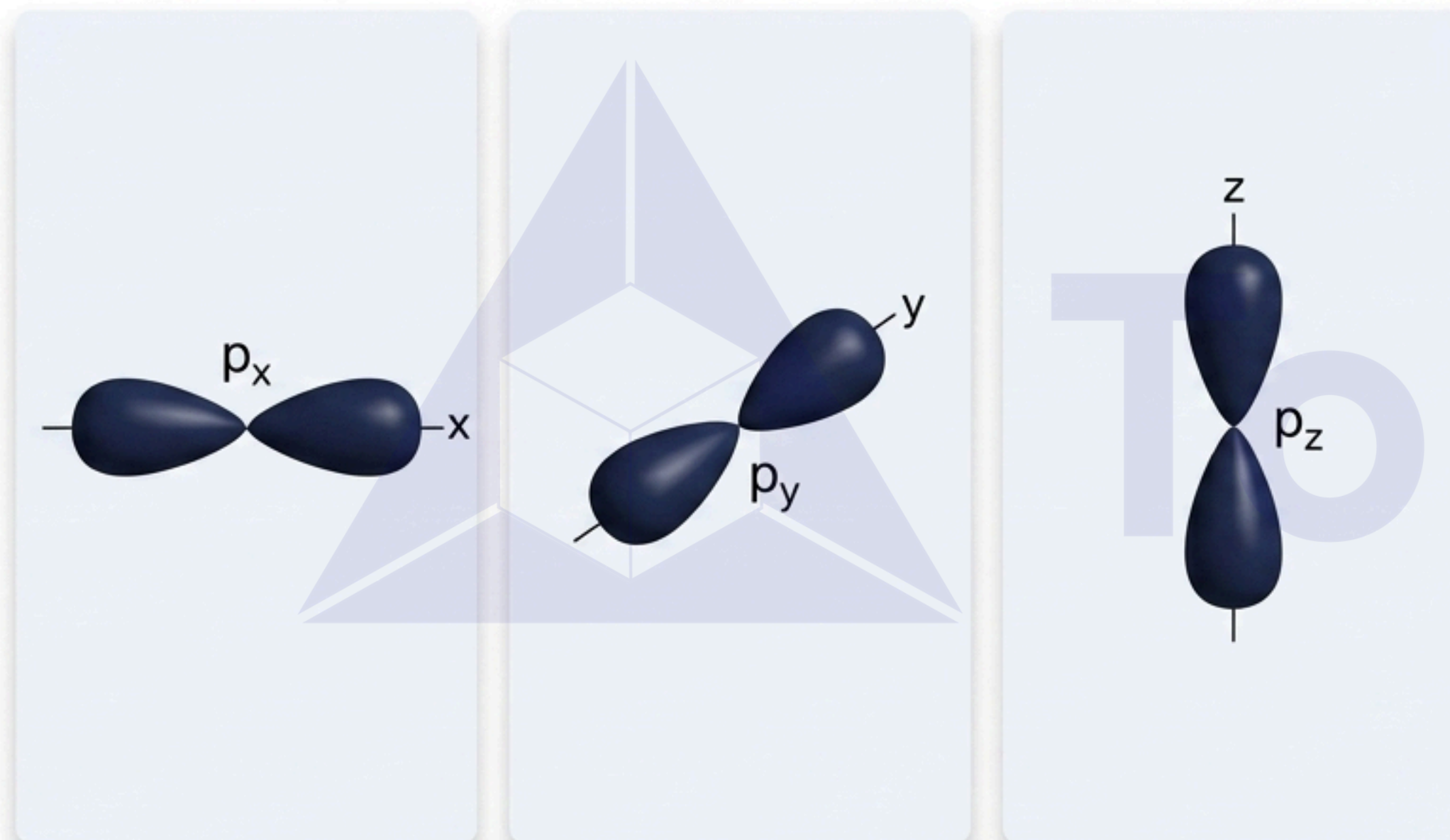


2s

Scale:

Size and energy increase as the principal quantum number (n) increases ($1s < 2s < 3s$).

The p-Orbitals



Shape: Dumbbell-shaped (two identical lobes).

Quantum Code:

$$l = 1$$

Orientations: 3 mutually perpendicular orbitals:
 p_x , p_y , p_z

Crucial Feature: The probability density drops to absolute zero on the plane where the two lobes touch (the nucleus).



You've Learned the Theory. Let's Test Them Now.

$$E=mc^2$$



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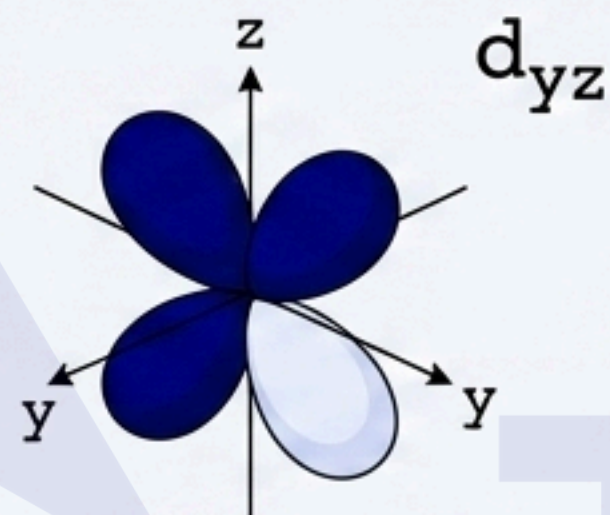
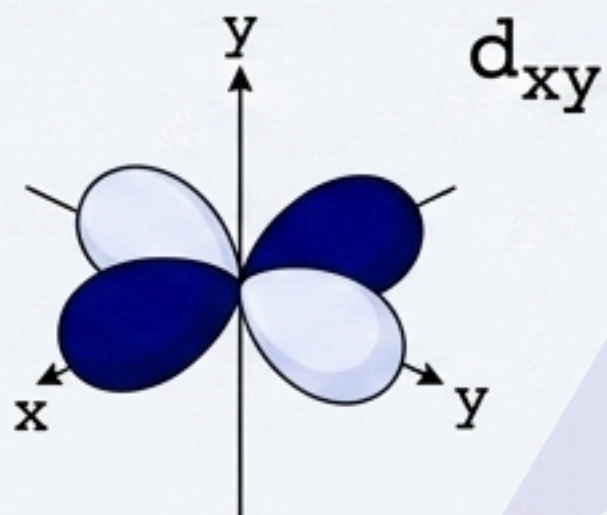
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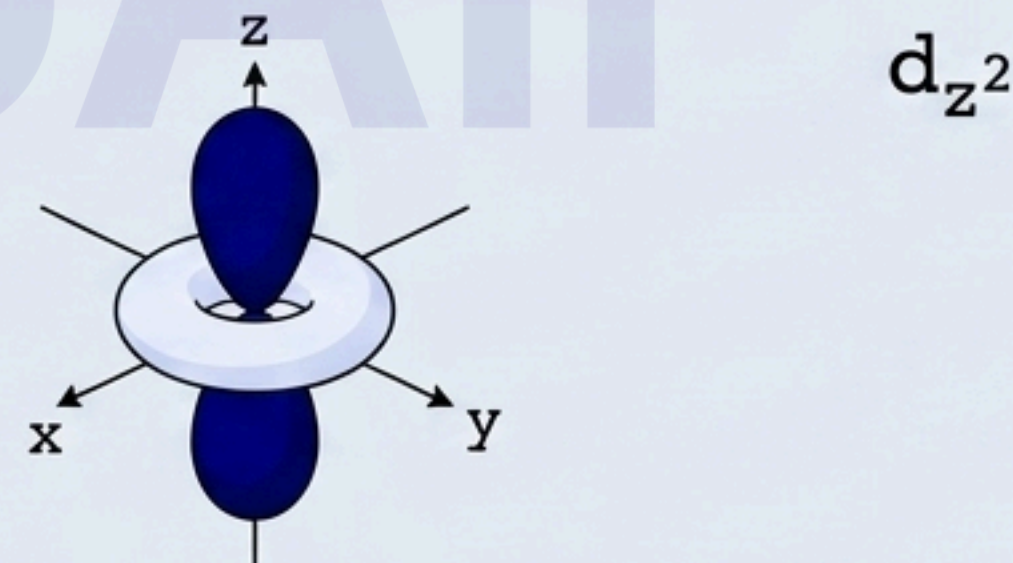
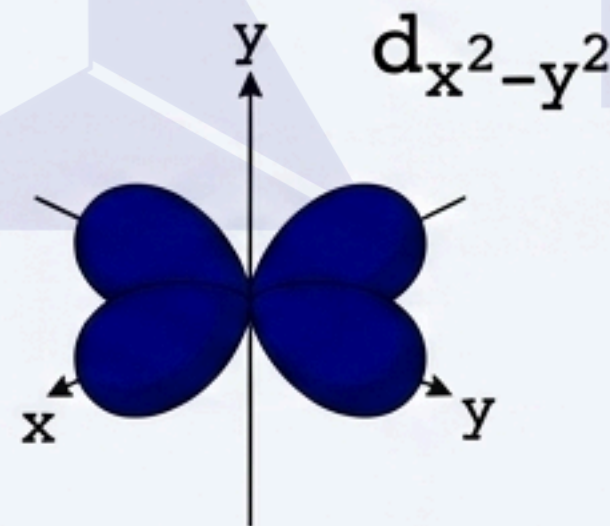
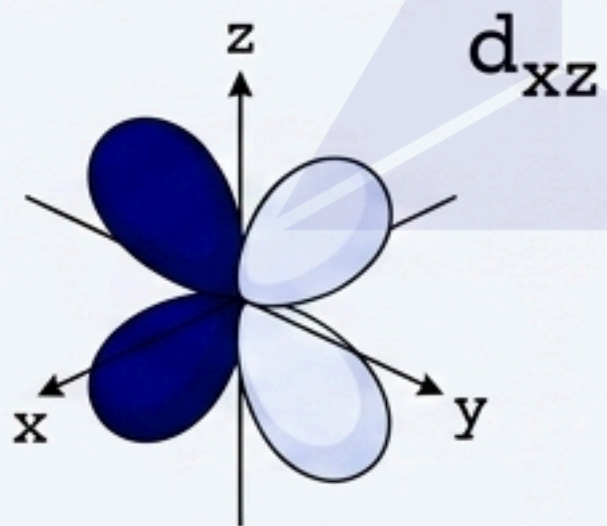
The d-Orbitals



Shape: Clover-leaf / Complex

Quantum Code: $l = 2$

Orbitals: d_{xy} , d_{yz} , d_{xz} , $d_{x^2-y^2}$, d_{z^2}

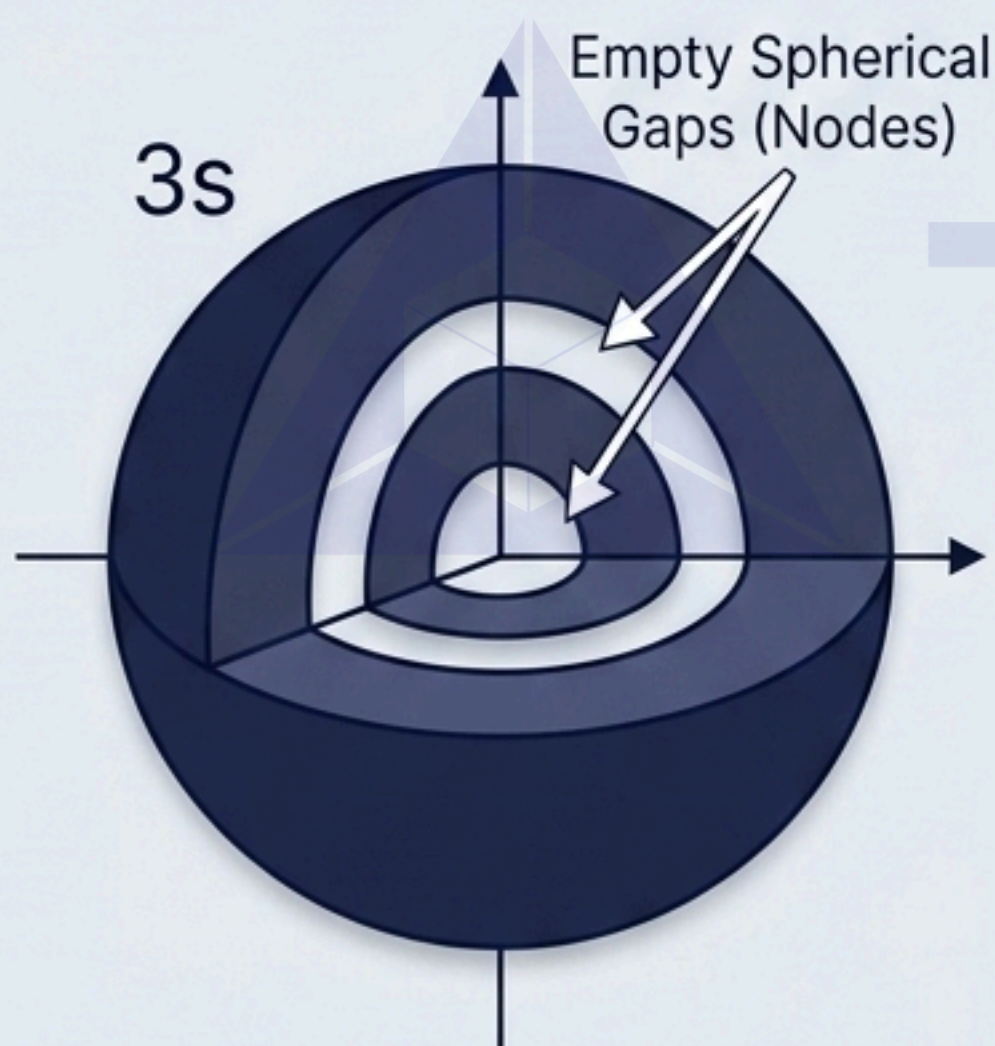


Note: All five 3d orbitals are degenerate (equivalent in energy in an isolated atom), despite the unique geometry of d_{z^2} .

Anatomy of a Node

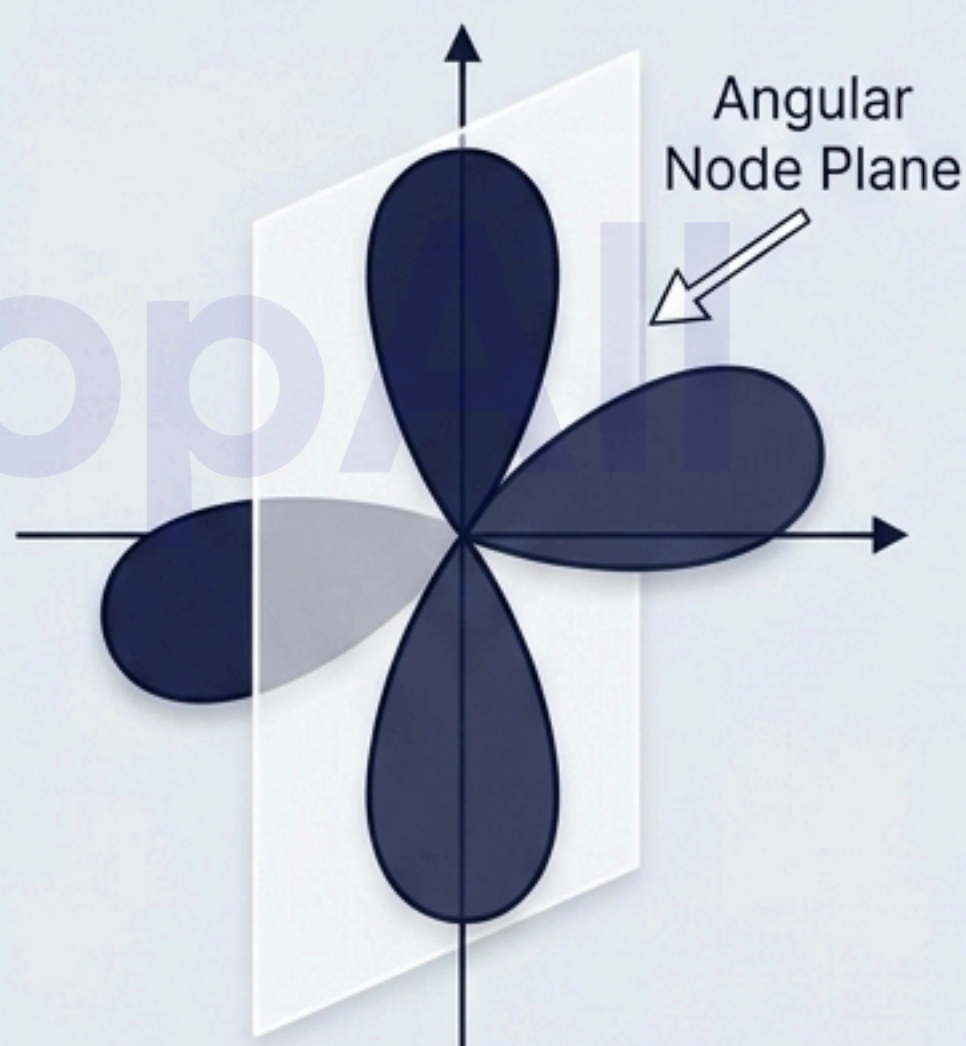
Concept: Nodes are regions of space where the probability of finding an electron drops to exactly zero ($|\psi|^2 = 0$).

Type 1: Radial Nodes



Spherical gaps expanding outward based on distance (r).

Type 2: Angular Nodes



Flat planes or cones slicing through the origin based on direction.

The Mathematics of Nodes

$$\text{Angular Nodes} = \ell$$

$$\text{Radial Nodes} = n - \ell - 1$$

$$\text{Total Nodes} = n - 1$$

This nodal mathematics is the most heavily tested concept in quantum mechanical orbital questions.

Synthesis Comparison Matrix

Orbital	Shape	ℓ value	Orientations	Angular Nodes
s-orbital	Spherical	0	1	0
p-orbital	Dumbbell	1	3	1
d-orbital	Double Dumbbell*	2	5	2

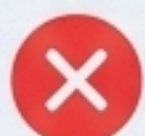
*(Four are clover-shaped; d_{z^2} is a lobe with a central torus).

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Caution: Formula Mix-Up

Do not confuse the total node formula ($n - 1$) with the radial node formula ($n - l - 1$). Read the question carefully.



Exam Trap: The Anomaly

The d_{z^2} orbital is heavily tested because its shape (lobe + torus) is anomalous compared to the other four clover-shaped d -orbitals.



Key Takeaway: Mathematical Constructs

Orbitals are not physical containers or shells; they are purely mathematical probability models (wave functions) representing electron density.



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