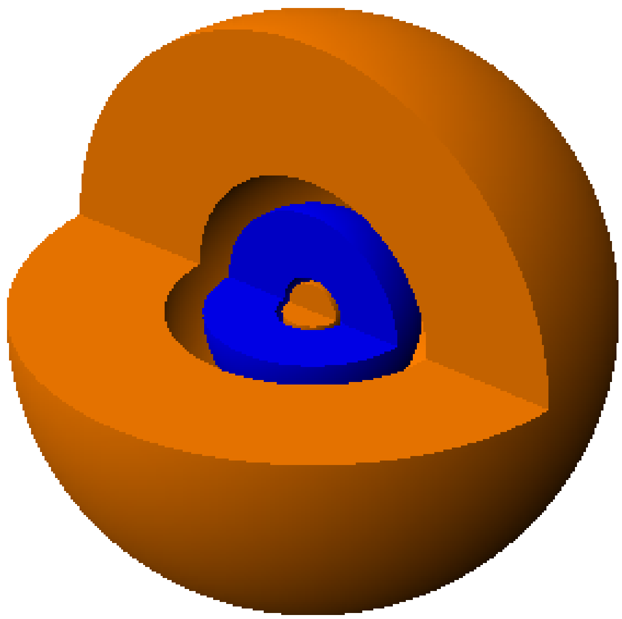
Cutaway Model of 3*s* Orbital

$n = 3$, $l = 0$, $m_l = 0$



The 3*s* orbital has two spherical nodes.

3p Orbitals

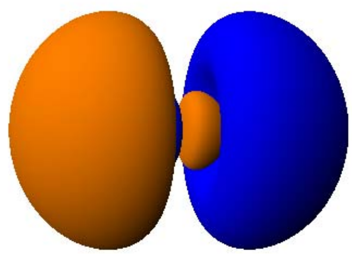
$n = 3$, $l = 1$, $m_l = +1, 0, -1$

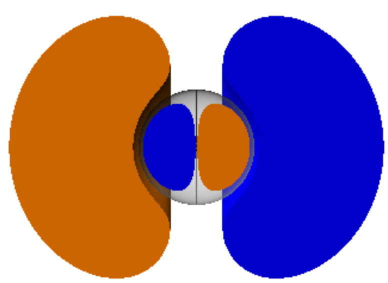
Three degenerate 3p orbitals, oriented along the axes of the coordinate system (3p_x, 3p_y, 3p_z).

More extensive (bigger) than 2p with additional lobes.

In addition to the nodal plane, inner lobes are separated from outer lobes by a spherical node.

3p_x

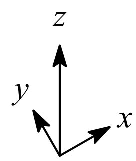


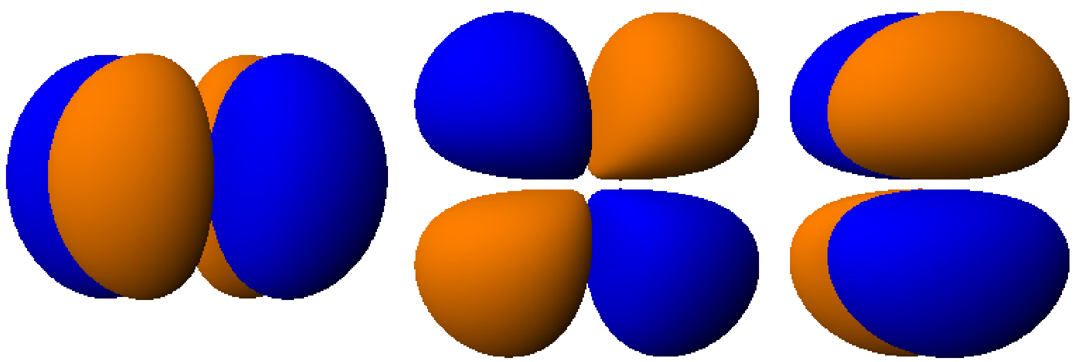


Cutaway model showing nodes

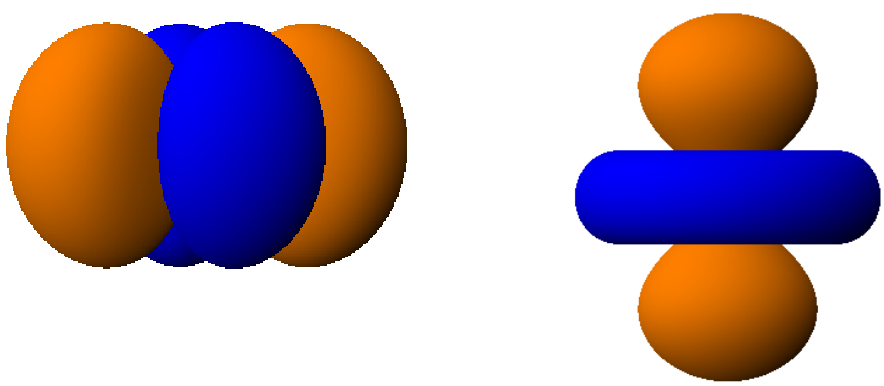
3*d* Orbitals

$n = 3$, $l = 2$, $m_l = +2, +1, 0, -1, -2$





$3d_{xy}$ $3d_{xz}$ $3d_{yz}$



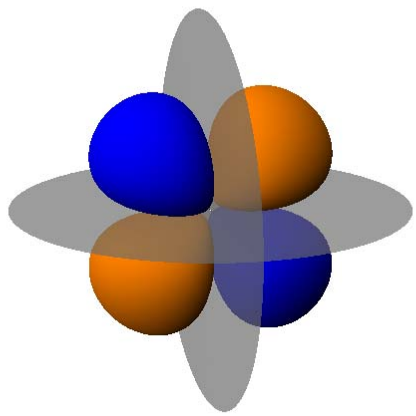
$3d_{x^2-y^2}$ $3d_{z^2}$

L The $3d_{xy}$, $3d_{xz}$, and $3d_{yz}$ orbitals' lobes are *between* the axes in their names.

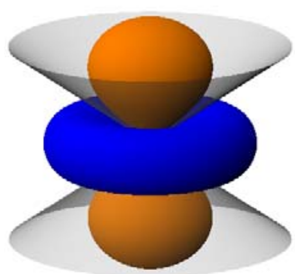
L The $3d_{x^2-y^2}$ orbital's lobes are *on* the x and y axes.

Nodes of 3*d* Orbitals

L “Cloverleaf” shaped 3*d* orbitals have two nodal planes intersecting at the nucleus, which separate the four lobes.



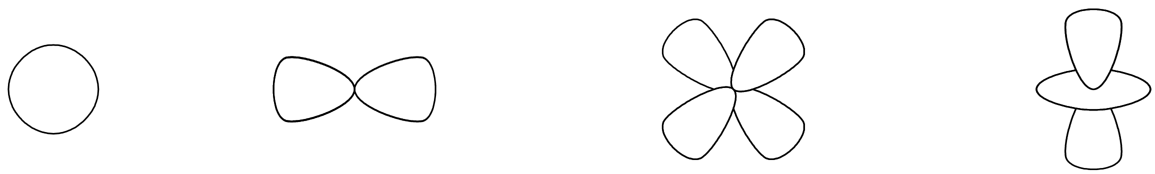
L The $3d_{z^2}$ orbital has two nodal cones whose tips meet at the nucleus, which separate the “dumbbell” lobes from the “doughnut” ring.



Quantum Numbers and Orbitals

n	l	m_l	Orbitals
1	0	0	1s
2	0	0	2s
2	1	-1, 0, +1	$2p_x$, $2p_y$, $2p_z$
3	0	0	3s
3	1	-1, 0, +1	$3p_x$, $3p_y$, $3p_z$
3	2	-2, -1, 0, +1,+2	$3d_{xz}$, $3d_{yz}$, $3d_{xy}$, $3d_{x^2-y^2}$, $3d_{z^2}$
4	0	0	4s
4	1	-1, 0, +1	$4p_x$, $4p_y$, $4p_z$
4	2	-2, -1, 0, +1, +2	$4d_{xz}$, $4d_{yz}$, $4d_{xy}$, $4d_{x^2-y^2}$, $4d_{z^2}$
4	3	-3, -2, -1, 0, +1, +2, +3	4f (7 orbitals)

"Balloon" Models of Atomic Orbitals for Routine Sketching



s *p* “cloverleaf” *d* d_{z^2}

Summary
Orbitals in One-electron Atoms (H, He^+, Li^{2+}, ...)

1. All orbitals with the same value of the principal quantum number n have the same energy; e.g., $4s = 4p = 4d = 4f$. (This is *not* true for multielectron atoms.)

2. The number of equivalent (degenerate) orbitals in each subshell is equal to $2l + 1$.

3. For orbitals with the same l value, size and energy increase with n; e.g., $1s < 2s < 3s$.

4. For orbitals of the same l value, the number of nodes increases with n.

Orbital	1*s*	2*s*	3*s*	4*s*
Nodes	0	1	2	3
Orbital		2*p*	3*p*	4*p*
Nodes		1	2	3