Announcements for Thursday, 19SEP2024

- Conflicts with Exam 1 on Tuesday, 01OCT2024, 7:45 – 9:05 PM
  - Due by **Friday, 20SEP2024, 11:59 PM (EDT)**
  - See Canvas Announcement from 16SEP2024 for more details
- Week 3 Homework Assignments available on Canvas/eLearning
  - Graded and Timed Quiz 3 – "Atoms" due **Monday, 23SEP2024, at 6:00 PM (EDT)**
  - **Readiness Assessment** is **re-opened; Final Deadline of Thursday, 19SEP2024, at 11:59 PM (EDT)**
  - *Metacognition* Digital Badge Assignment due **Friday, 20SEP2024, at 11:59 PM (EDT)**
- Teaching Intern (TI) Problem-Solving Sessions and Office Hours Begin This Week
  - Check "TIs' schedule" page on Canvas for more information
- Any **TECHNICAL ISSUES** associated with eLearning (quizzes, practice assignments, etc.) must be reported to **eLearning Tech Support** **(https://techsupport.elearning.rutgers.edu)**

ANY GENERAL QUESTIONS? Feel free to see me after class!

Try This On Your Own

What is the total energy of 2 dozen photons having a wavelength = 523.4 nm?

$$2\ dozen\ photons \times \frac{12\ photons}{1\ dozen\ photons} = 24\ photons$$

$$\lambda = 523.4\ nm \times \frac{1\ m}{10^9 nm} = 5.234\text{x}10^{-7} m$$

$$Energy\ of\ a\ single\ photon = h\nu = \frac{hc}{\lambda} = \frac{(6.626\text{x}10^{-34} J \cdot s)(2.998\text{x}10^{8} m/s)}{(5.234\text{x}10^{-7} m)} = 3.795\text{x}10^{-19} J/photon$$

$$Energy\ of\ 24\ photons\text{:}\ \ 24\ photons \times \frac{3.795\text{x}10^{-19}\ J}{1\ photon} = 9.109\text{x}10^{-18} J$$

Try These On Your Own

- In 1.0 s, a certain lamp gives out 25 J of energy in the form of yellow light of wavelength 580. nm. How many photons of yellow light does the lamp generate in 1.0 s? **7.30×10^{19} photons**
- What is the wavelength (nm) of light that has an energy content of 487 kJ/mol photons? **246 nm**
- The photoelectric effect for mercury is observed when the energy of the photon is not less than 7.25×10^{-19} J.
  - What is the maximum wavelength of light (nm) that causes the photoelectric effect in mercury? **274 nm**
- The threshold energy of lithium metal is 4.65×10^{-19} J. Upon irradiation, an electron is ejected from the surface of lithium with a kinetic energy of 2.00×10^{-19} J. Calculate the energy of light used to irradiate the lithium metal. **6.65×10^{-19} J**

Try This On Your Own

The electron in the hydrogen atom undergoes a transition from n = 4 to n = 2. Determine the wavelength of the photon (nm) associated with this transition and determine if the photon is absorbed or released.

$n_{final} = 2$ $n_{initial} = 4$

$$\Delta E = h\nu = \frac{hc}{\lambda} = -2.179\text{x}10^{-18} J\left(\frac{1}{{n_f}^2} - \frac{1}{{n_i}^2}\right)$$

$$\frac{hc}{\lambda} = -2.179\text{x}10^{-18} J\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = -4.086x10^{-19} J$$

photon released

$$\lambda = \frac{(6.626x10^{-34} Js)(2.998x10^{8} m/s}{4.086x10^{-19} J} = 4.862x10^{-7} m$$

$$\lambda = 4.862x10^{-7} m \times \frac{10^9\ nm}{1\ m} = 486.2\ nm\ released$$

Atomic Orbitals: Where Electrons Live

- it turns out there is more to the arrangement of electrons than just Bohr's principal energy levels (values of n)
- **atomic orbital =** a region of space around the atom's nucleus where there is a high probability of finding an electron
  - **atomic orbitals are actually mathematical constructs that result from treating electrons as waves**
- every atomic orbital in an atom is specified by a group of three numbers (called quantum numbers) that designate different properties of the orbitals such as energy, size, shape, and orientation in space
  - a fourth quantum number designates a particular electron in a particular orbital
- think of the first three quantum numbers as designating the address of every electron (like the town, the street, and the house number of each electron)
  - the town = the principal/main energy level
  - the street = a particular subshell of the main energy level
  - the house = a particular orbital of a subshell of a main energy level
- all electrons in an atom reside in a particular principal energy level, in a particular subshell, and in a particular orbital
  - only two electrons can reside in a given atomic orbital (more to come)

Quantum Numbers: What they are and what they tell us

- **<u>principal quantum number (n)</u>**
  - possible values: positive whole numbers where n = 1, 2, 3…

- designates the principal energy level (the town)
  - it’s the same as Bohr’s energy levels
  - also tells you how many subshells compose the energy level
  - as the value of n increases, more subshells make up the energy level

- the higher the value of n
  - the further away from the nucleus the electrons are
  - the higher the energy of the electrons in the energy level

Quantum Numbers: What they are and what they tell us

- **angular momentum quantum number (ℓ)**
  - possible values depend on first specifying a value of n
  - ℓ = integer values and zero ranging from 0 to n-1

Value of l	Letter Designation
$l = 0$	*s*
$l = 1$	*p*
$l = 2$	*d*
$l = 3$	*f*

- designates a specific subshell within a principal energy level (the street) and designates the shapes of the orbitals within the subshell
  - when ℓ = 0, the subshell is called the s-subshell with an s-orbital (shapes to come)
  - when ℓ = 1, the subshell is called the p-subshell with p-orbitals (shapes to come)
  - when ℓ = 2, the subshell is called the d-subshell with d-orbitals (shapes to come)
  - when ℓ = 3, the subshell is called the f-subshell with f-orbitals (shapes to come)

- all principal energy levels have an s-subshell
- p-subshells don't occur until the n = 2 principal energy level
- d-subshells don't occur until the n = 3 principal energy level
- f-subshells don't occur until the n = 4 principal energy level

Quantum Numbers: What they are and what they tell us

- **magnetic quantum number (m_ℓ)**
  - possible values depends on first specifying a value of n **and** ℓ
  - possible values: positive and negative whole numbers (and zero) where m_ℓ ranges from +ℓ to 0 to –ℓ

- designates a specific orientation in space of the atomic orbital (the house)

- the number of m_ℓ values for a specific value of ℓ gives the number of individual atomic orbitals composing the subshell
  - for ℓ = 0, m_ℓ can only = 0. **one** m_ℓ value → only **one orbital** makes up the s-subshell
  - for ℓ = 1, m_ℓ = +1, 0, and –1. **three** m_ℓ values means **three different orbitals** make up the p-subshell
  - for ℓ = 2, m_ℓ = +2, +1, 0, –1, and –2. **five** m_ℓ values means **five different orbitals** make up the d-subshell
  - for ℓ = 3, m_ℓ = +3, +2, +1, 0, –1, –2, and –3. **seven** m_ℓ values means **seven different orbitals** make up the f-subshell

Quantum Numbers: What they are and what they tell us

- **magnetic spin number (m_s)**
  - only two possible values: $m_s = \pm 1/2$

- designates the spins **of the electrons** in an orbital
  - spin up vs. spin down or clockwise vs. counter-clockwise
  - if two electrons are sharing the same atomic orbital, the electrons have the same values of n, ℓ, and m_ℓ
  - BUT the electrons MUST have different m_s values ($m_s = +\frac{1}{2}$ or $m_s = -\frac{1}{2}$)
  - we'll come back to this in Chapter 3

Atomic Orbitals and Quantum Numbers

designates a **particular electron**
in the **atomic orbital**

$$\overbrace{\underbrace{n \quad \ell \quad m_\ell}_{\text{designates a particular atomic orbital}} \quad m_s}^{\text{designates a particular electron in the atomic orbital}}$$

designates a particular
atomic orbital

To Sum Up Quantum Numbers n, ℓ, and m_ℓ

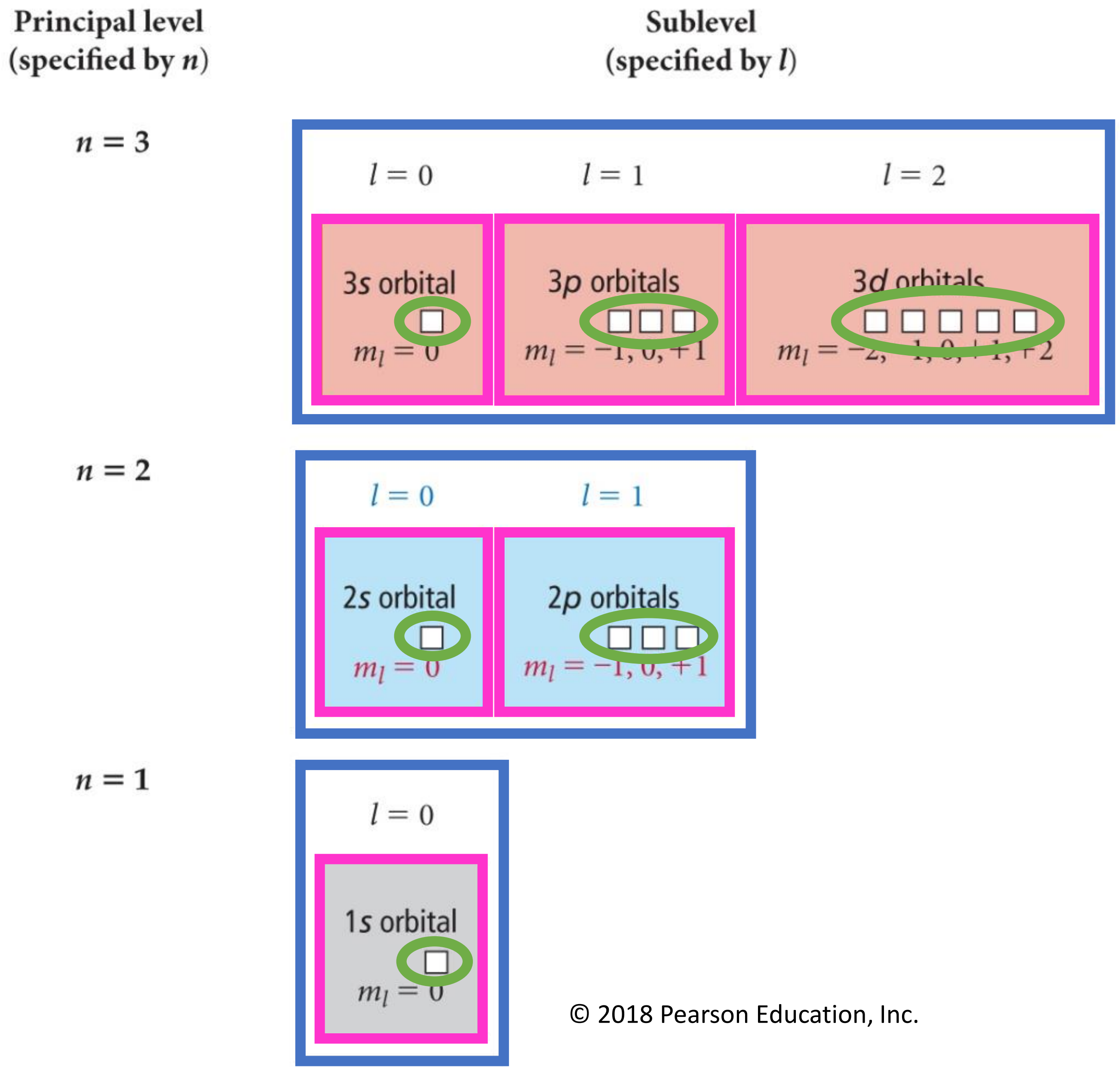
principal energy levels (n)

↓

subshells (ℓ)

↓

individual orbitals (m_ℓ)



Practical skills related to quantum numbers

- if given a set of quantum numbers, you should be able to identify the principal energy level, the sublevel, and the atomic orbital
  - for example, which orbital is designated by $n = 5$, $\ell = 3$, and $m_\ell = -2$

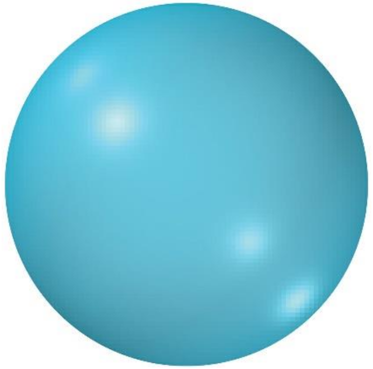
It's a 5f orbital

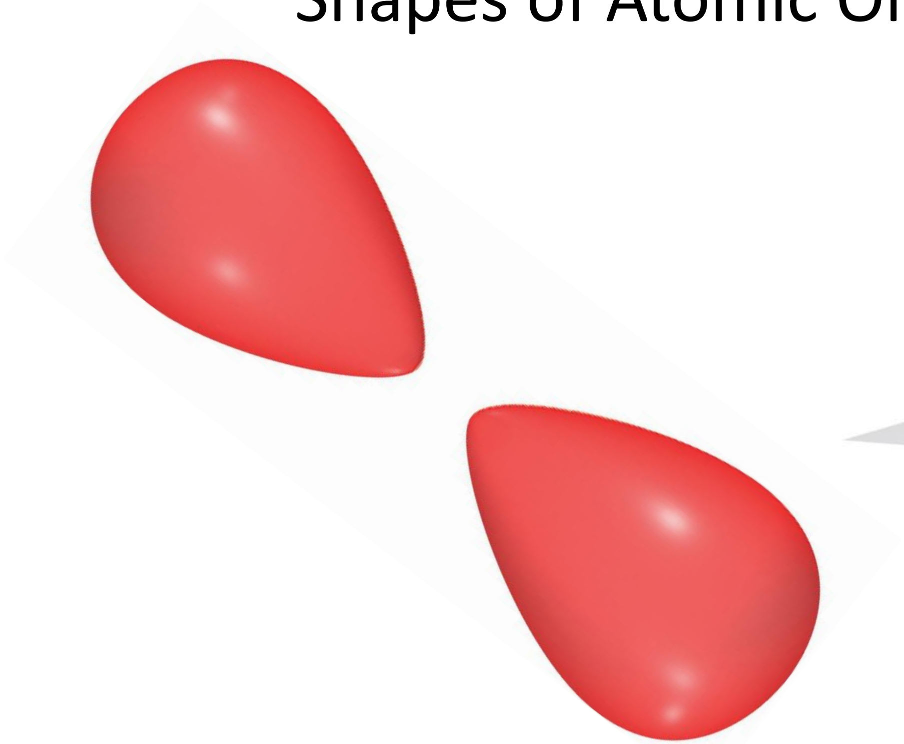
- you should be able to determine if a given set of quantum numbers is possible or not
  - for example is the following set possible? $n = 2$, $\ell = 2$, $m_\ell = 0$, and $m_s = +½$ why/why not?

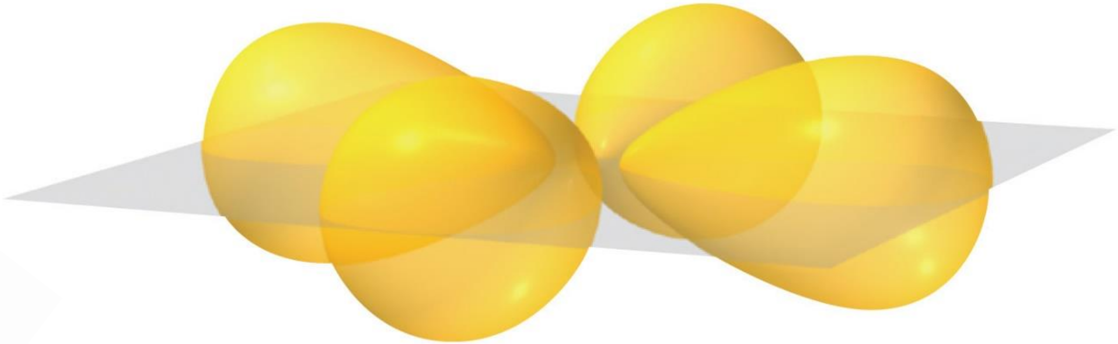
No, the ℓ value is not possible based on the value of n

For Next Lecture: Write down the all the possible n, ℓ, m_ℓ designations for the orbitals composing the **fourth principal energy level**. Answers given next lecture.

Shapes of Atomic Orbitals



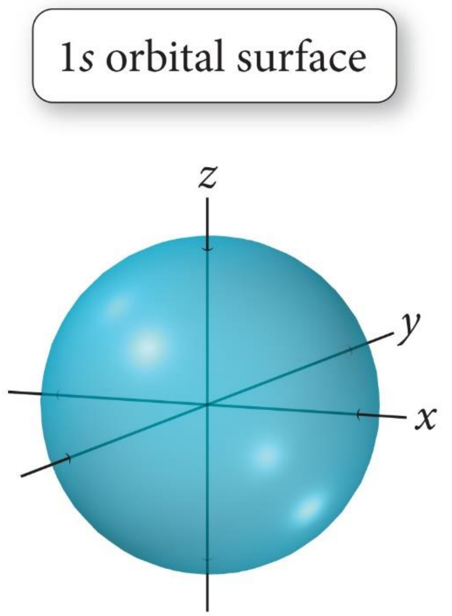


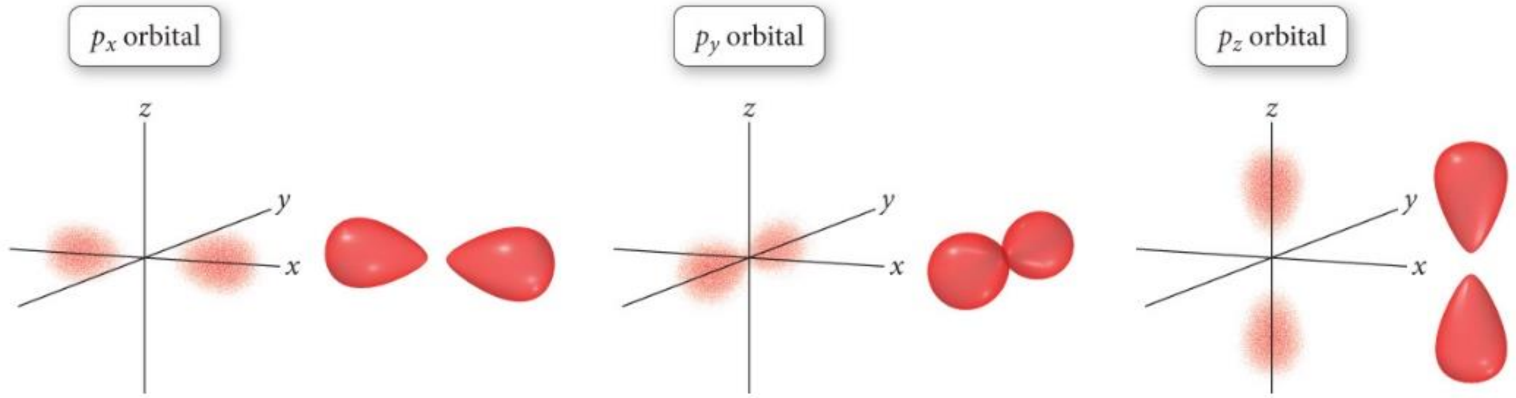


Why are the shapes of atomic orbitals important?

- the shapes and orientations of orbitals around an atom will impact the shapes of molecules
  - shapes of molecules impact many important physical and chemical properties
- the shapes of the orbitals also impact the types of bonds the orbitals can make
  - sigma vs. pi bonds (Chapter 6)

s-orbitals and p-orbitals

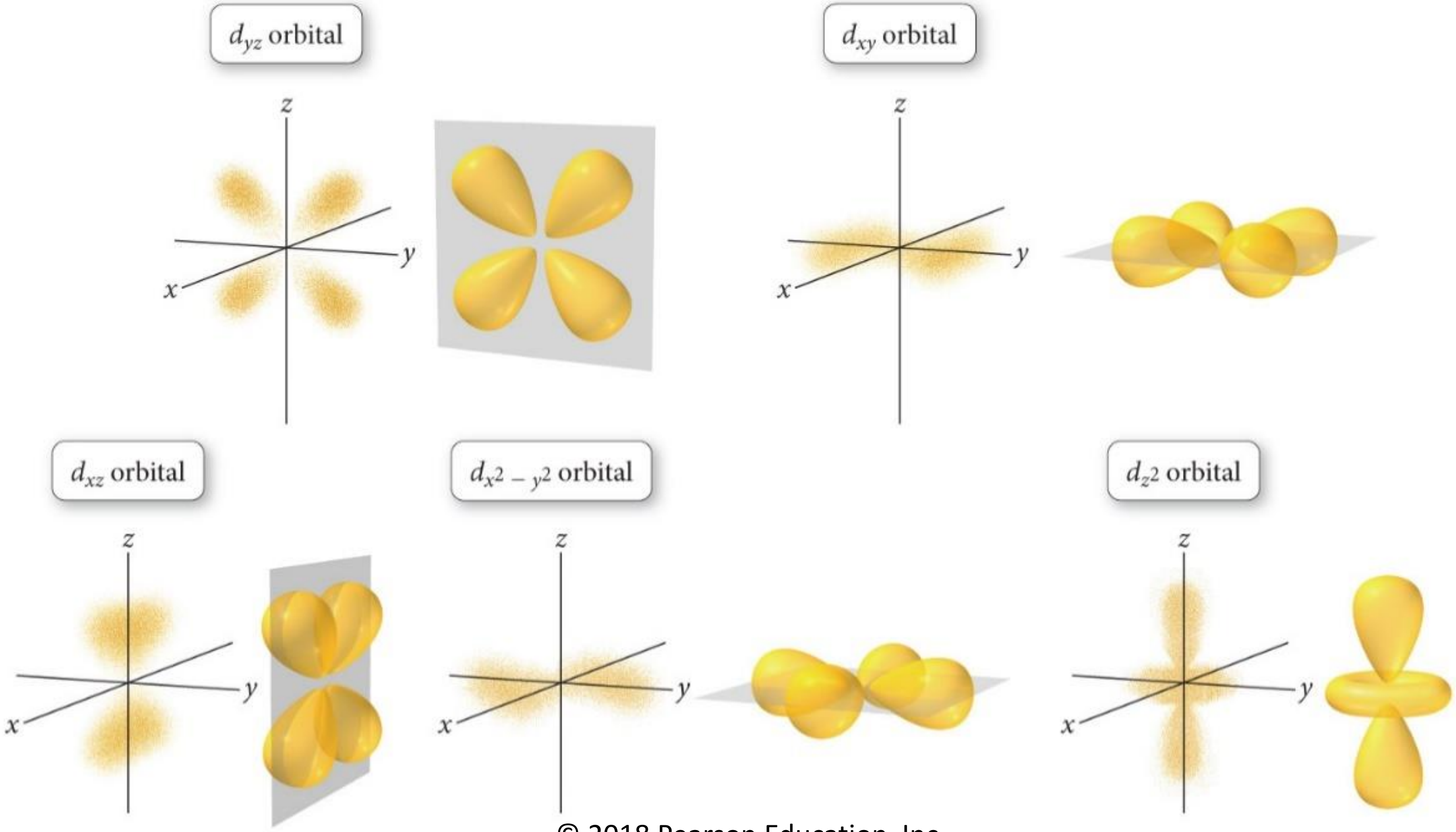




- $\ell = 0$, $m_\ell = 0$
- only one 3-D orientation in space
- 2s, 3s, 4s orbitals… are larger and contain nodes

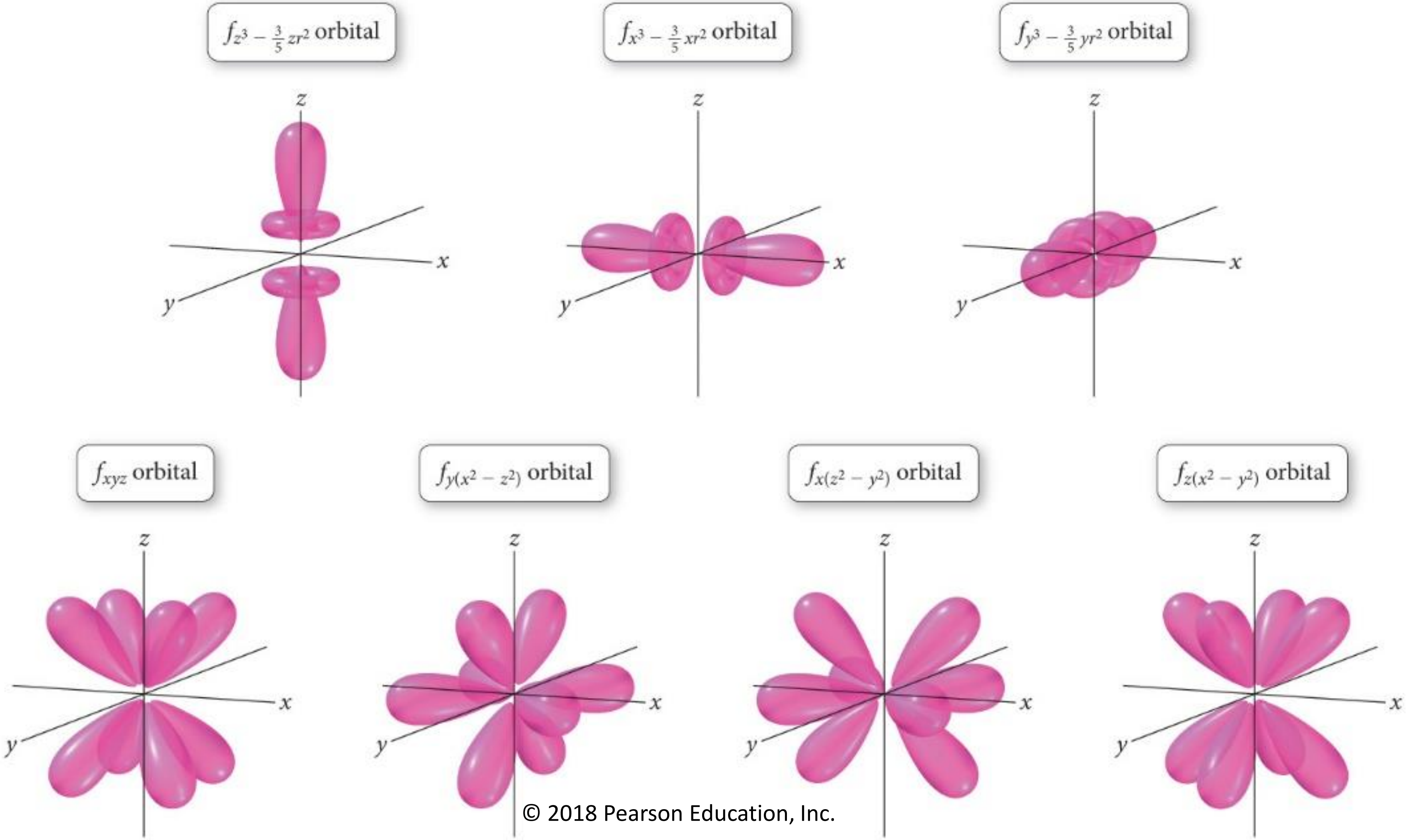
- $\ell = 1$, $m_\ell = +1, 0, -1$
- three orientations in space
- lobes align parallel to an x-, y- or z-axis
- two lobes = 1 orbital

d-orbitals



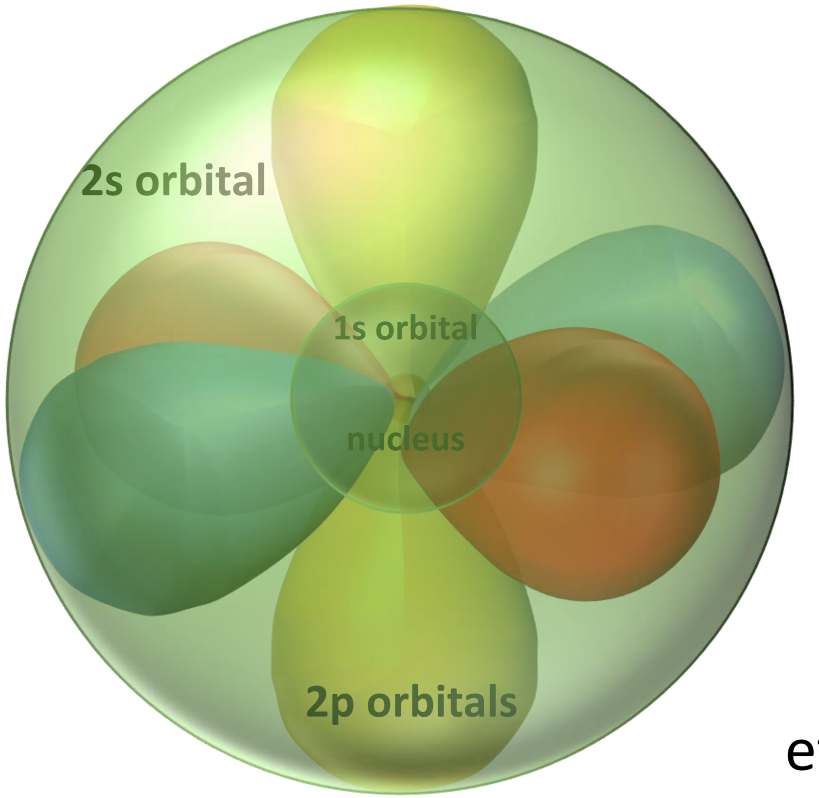
- ℓ = 2, m_ℓ = +2, +1, 0, –1, –2
- 5 orientations in space
- lobes oriented parallel along two different axes (planes)
- four lobes or two lobes + donut = 1 orbital
- don't memorize the names

f-orbitals



- $\ell = 3$, $m_\ell = +3, +2, +1, 0, -1, -2, -3$
- 7 orientations in space

Orbital Arrangement Around the Nucleus



etc.