Quantum Numbers

Chapter 3.4

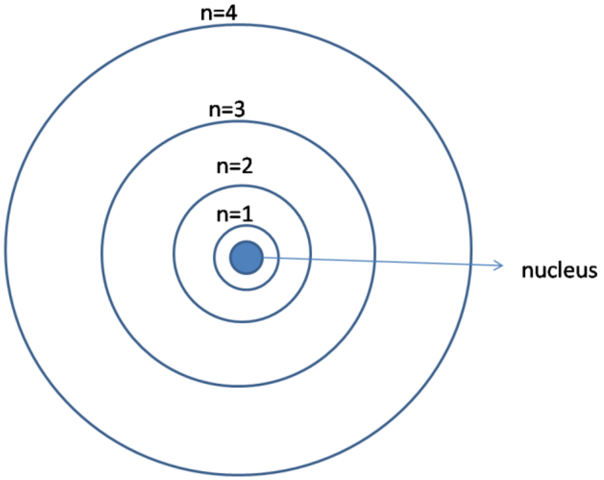
The Four Quantum Numbers

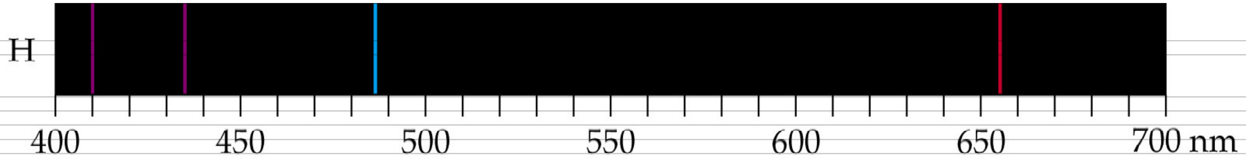
- **Quantum Numbers** are numbers that describe the quantum mechanical properties of orbitals

1. The Principal Quantum Number (n)
2. The Secondary Quantum Number (l)
3. The Magnetic Quantum Number (m_l)
4. The Spin Quantum Number (m_s)

The Principal Quantum Number (*n*)

- Gives the main energy level or *shell*
- Describes the **size** and **energy** of an atomic orbital
- n can have any integer value greater than zero
  n = 1, 2, 3, 4, …



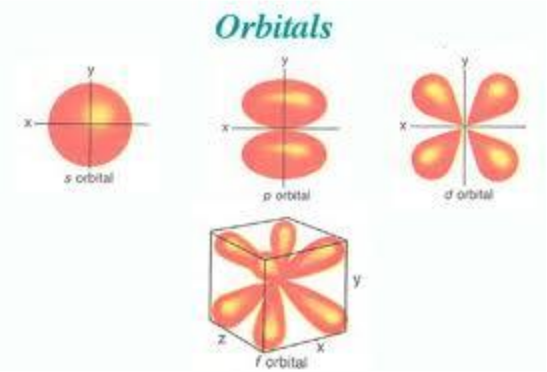


The Secondary Quantum Number (*l*)

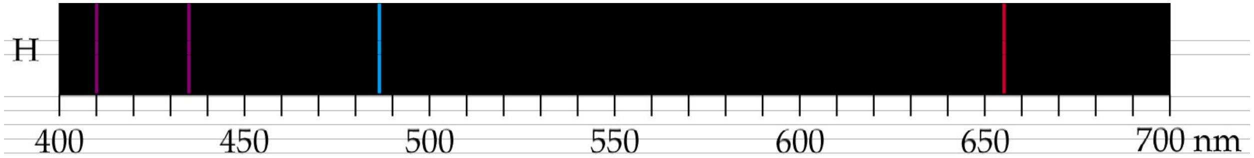
l =	0	1	2	3
	s	p	d	f

- Gives the sublevel or *subshell*
- Describes the **shape** of the orbital:
- Sometimes called the 'Angular Momentum Quantum Number'
- *l* can have any integer values from 0 to n-1
  e.g.

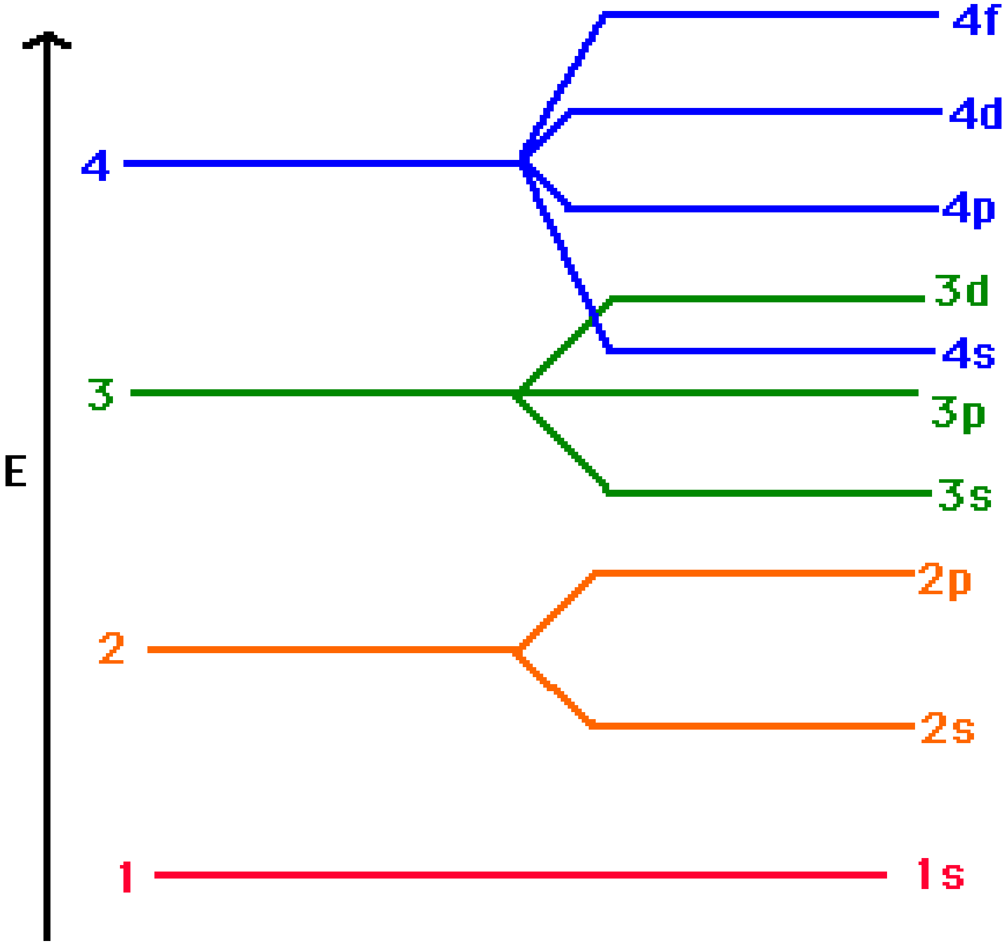
n	l
1	0
2	0,1
3	0,1,2
4	0,1,2,3



- The energy of the orbital depends on *l* only in a multi-electron case; for electrons with the same n, energy of *l*=1 < *l*=2 < *l*=3…
- Albert Michaelson worked with high resolution spectra and discovered that the lines in the hydrogen atom's spectrum were actually made up of multiple smaller lines



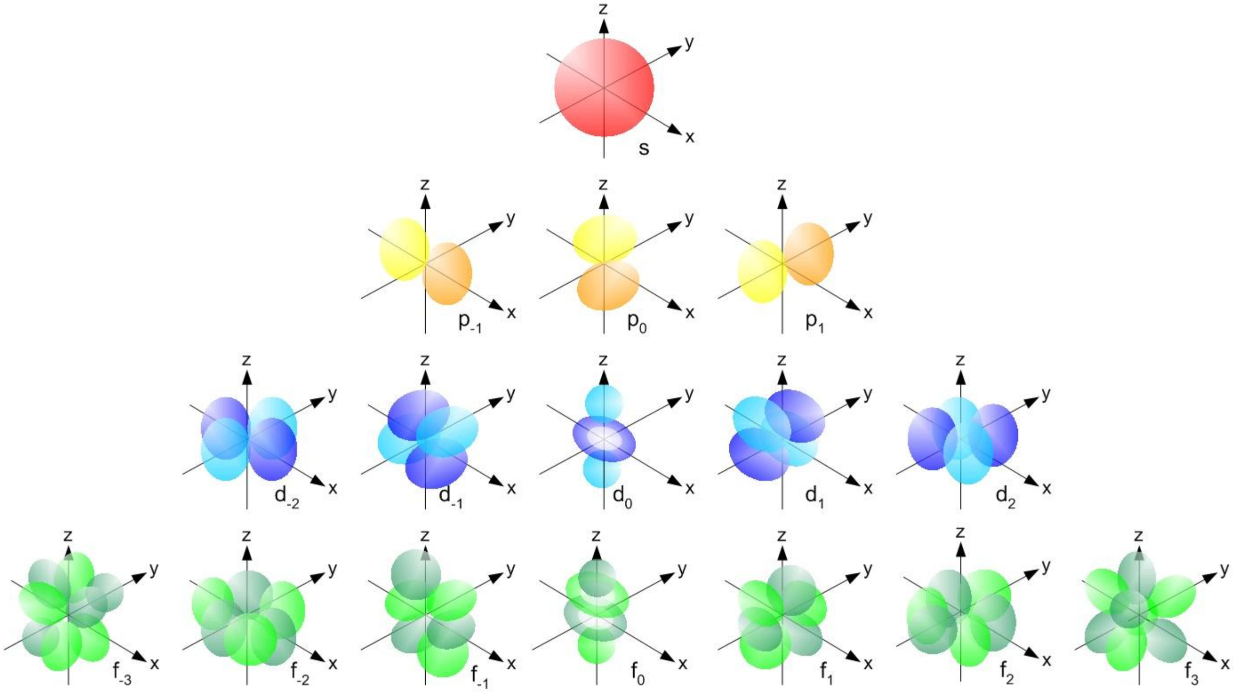
Subshell Overlap



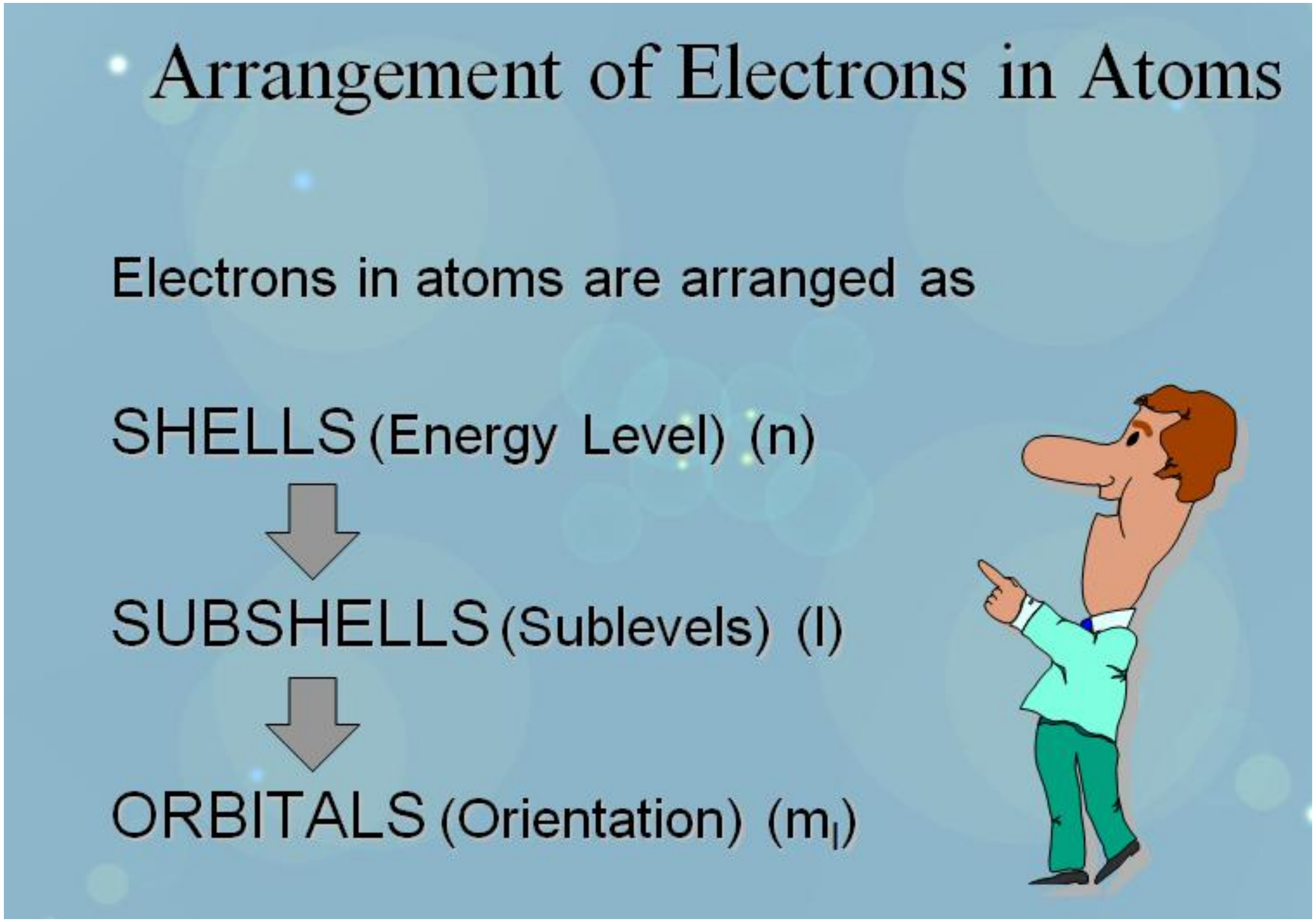
The Magnetic Quantum Number (m_l)

- Gives the exact *orbital*
- Describes the **orientation** of an atomic orbital in space (how it lines up on the xyz plane)
- m_l can have integer values from $-l$ to $+l$ including 0
- The Zeemen effect showed that if a gas discharge tube was placed near a strong magnet some single lines in the spectrum split into new lines that were not initially present

l	m_l
0	0
1	-1, 0, +1
2	-2, -1, 0, +1, +2
3	-3, -2, -1, 0, +1, +2, +3



So Far We Know This…



Arrangement of Electrons in Atoms

Electrons in atoms are arranged as

SHELLS (Energy Level) (n)

↓

SUBSHELLS (Sublevels) (l)

↓

ORBITALS (Orientation) (m_l)

The Spin Quantum Number (m_s)

- Gives the *spin state* of the electron
- Describes the direction in which the electron is spinning (identifies the electron within an orbital)
- Goudsmit and Uhlenbeck noticed that an atom has a magnetic moment when it is placed in an external magnetic field
- m_s can have only two possible values: +1/2 or -1/2

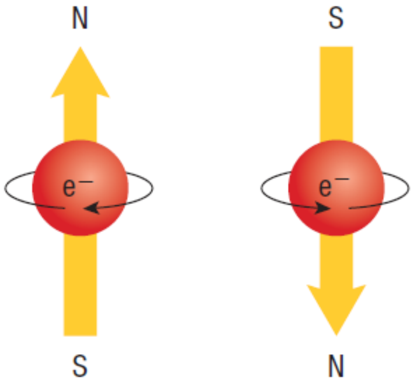
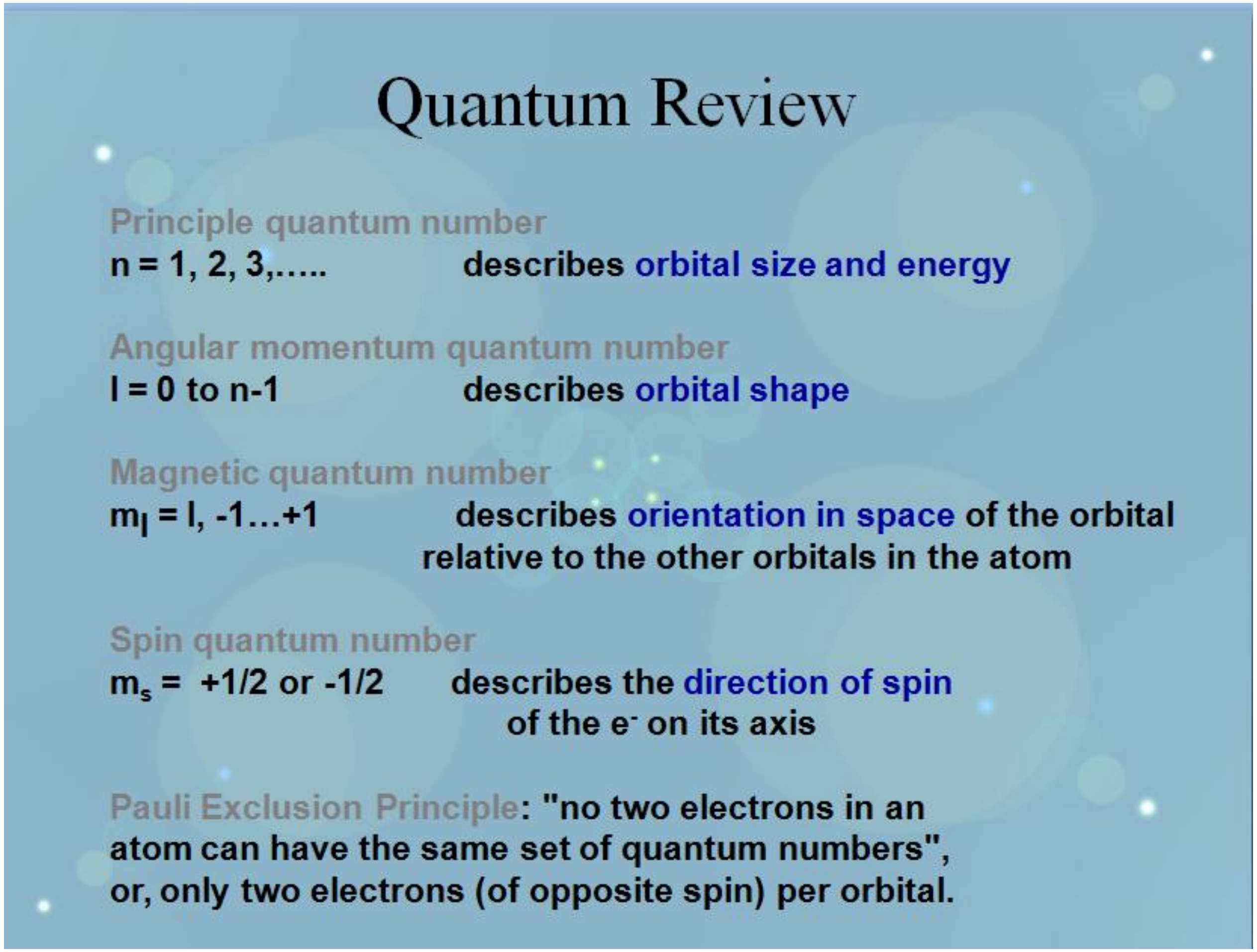


Figure 7 (a) By spinning in one direction, the electron produces a magnetic field oriented toward north. (b) By spinning in the opposite direction, the electron produces a magnetic field in the opposite orientation.

The Pauli Exclusion Principle

- In a given atom, no two electrons can have the same set of four quantum numbers (n, l, m_l, and m_s)
- An orbital (same n, l, and m_l) can hold a maximum of two electrons and they must have opposite spins (different m_s)

In Summary



Quantum Review

Principle quantum number

$n = 1, 2, 3, \ldots$ describes orbital size and energy

Angular momentum quantum number

$l = 0$ to $n-1$ describes orbital shape

Magnetic quantum number

$m_l = l, -1 \ldots +1$ describes orientation in space of the orbital relative to the other orbitals in the atom

Spin quantum number

$m_s = +1/2$ or $-1/2$ describes the direction of spin of the e^- on its axis

Pauli Exclusion Principle: "no two electrons in an atom can have the same set of quantum numbers", or, only two electrons (of opposite spin) per orbital.

Learning Check: Are These Valid Sets of Quantum Numbers?

(n, l, m_l, m_s)

- (1,0,1/2,1/2)
- (3,0,0,+1/2)
- (2,2,1,+1/2)
- (4,3,-2,+1/2)
- (3,2,1,1)

- List all the possible subshells and orbitals associated with the principal quantum number **n** if **n** =5. Indicate the number of electrons as you go.

- Which of these sets of quantum numbers describes an electron in a *4p* orbital?
  (4,2,2,1/2); (3,1,0,-1/2); (4,1,-1,1/2)

- Write the four quantum numbers for an electron in a *5p* orbital.

A Useful Formula

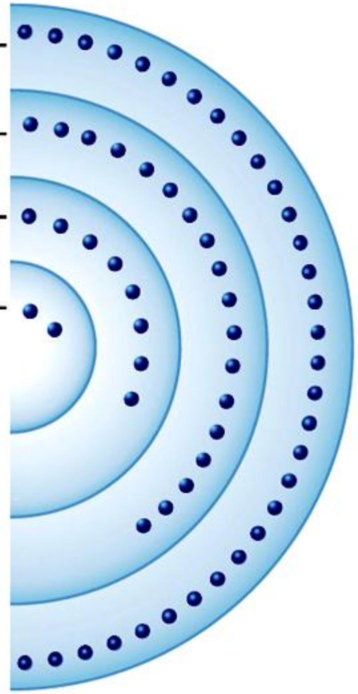
Maximum Electron Capacities of the First Four Shells

$n = 4$ $2n^2 = 2 \times 4^2 = 32$ electrons

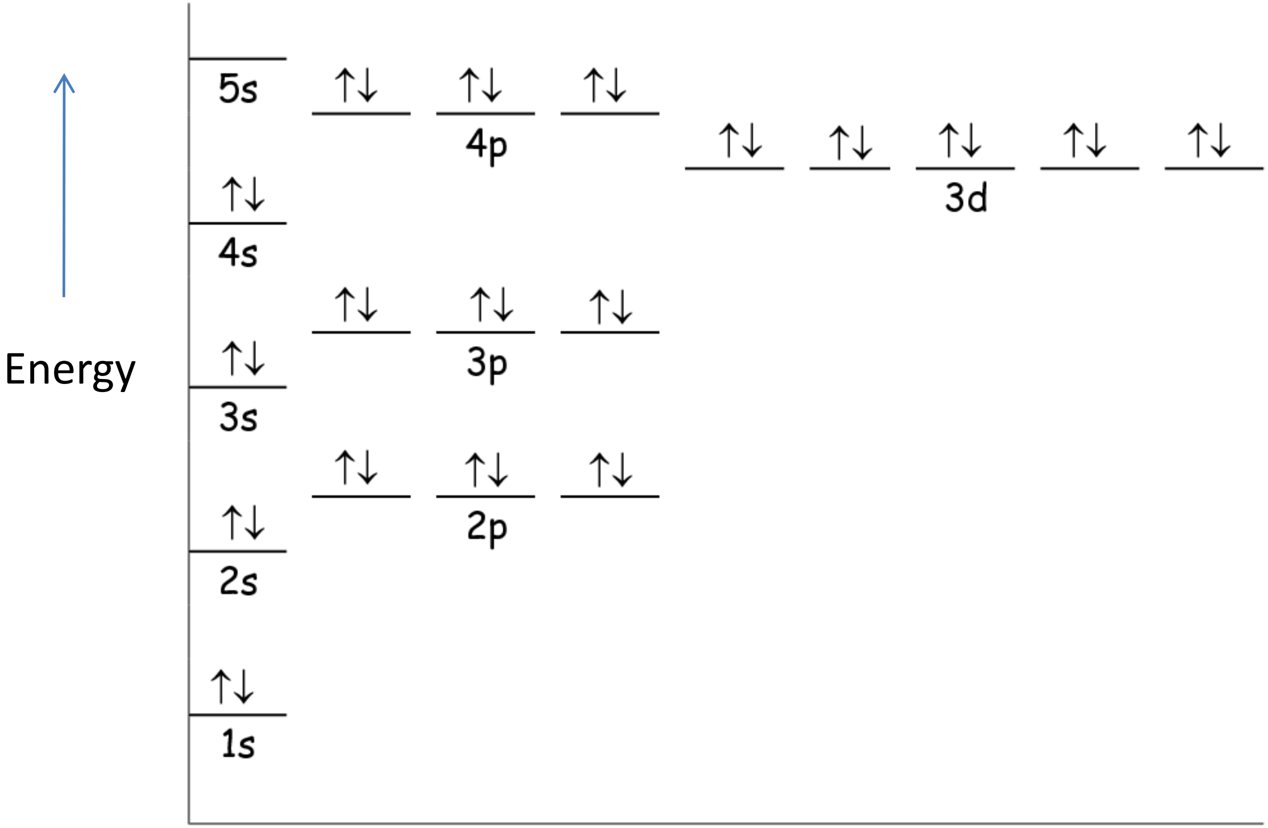
$n = 3$ $2n^2 = 2 \times 3^2 = 18$ electrons

$n = 2$ $2n^2 = 2 \times 2^2 = 8$ electrons

$n = 1$ $2n^2 = 2 \times 1^2 = 2$ electrons



Applying the Four Quantum Numbers



HOMEWORK

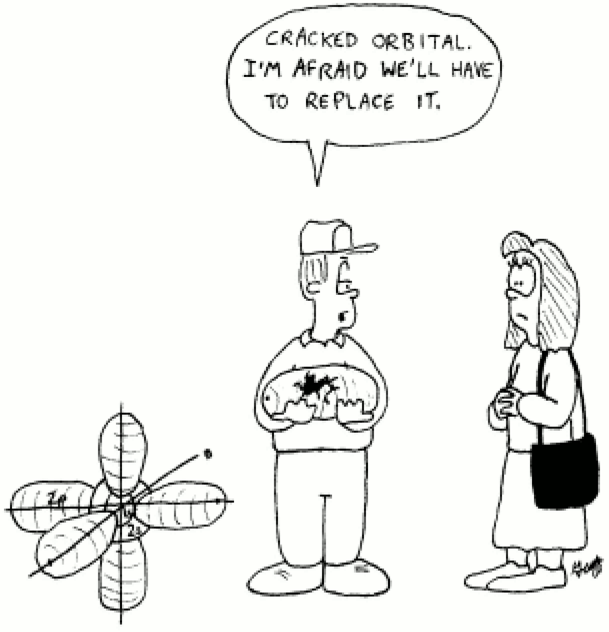
Required Reading:

p. 153-159

(remember to supplement your notes!)

Questions:

p. 159 #1-12



A QUANTUM MECHANIC