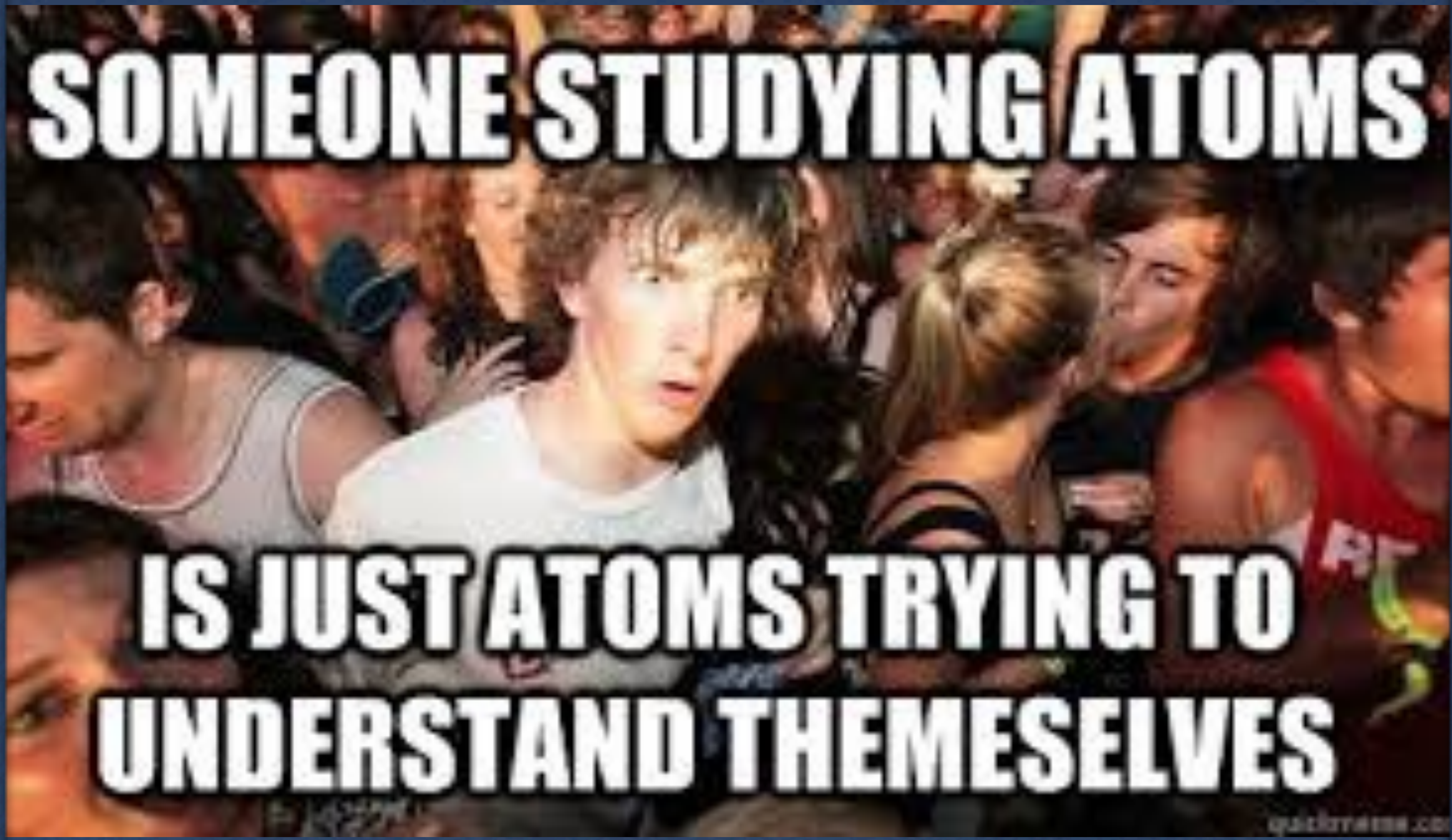


Electron Configuration

Wednesday 11/04/15

Agenda

- *Notes Electron Configuration*
- *Start handout on electron configuration and orbital diagrams*

Updates

- *I will have all tests, homework, classwork updated by this weekend.*
- *If you missed the exam you only have this week to make it up.*
- *I will not be in the tutoring center this week unfortunately.*

Topic 2.2
Electron configuration

- Emission spectra are produced when photons are emitted from atoms as excited electrons return to a lower energy level.
- The line emission spectrum of hydrogen provides evidence for the existence of electrons in discrete energy levels, which converge at higher energies.
- The main energy level or shell is given an integer number, n, and can hold a maximum number of electrons, $2n^2$.
- A more detailed model of the atom describes the division of the main energy level into s, p, d and f sub-levels of successively higher energies.
- Sub-levels contain a fixed number of orbitals, regions of space where there is a high probability of finding an electron.
- Each orbital has a defined energy state for a given electronic configuration and chemical environment and can hold two electrons of opposite spin.

Electron Configuration

Heisenberg's uncertainty principle questions:

1. The wavelength of a quantum object is determined by its:
   a. Position
   b. Momentum
   c. Composition
   d. Multiple properties
2. For a quantum particle to have a long wavelength, it should have:
   a. Have a large mass and move at high speed
   b. Hard a large mass and move at low speed
   c. Have a small mass and move at high speed
   d. Have a small mass and move at low speed
3. Adding together multiple waves to make a wave packet means that:
   a. There are multiple particles in the packet, each with a different wavelength
   b. There are multiple particles in the packet, each with a different position
   c. The object has a single momentum but can be found in one of many positions
   d. The object has a single position but can be found in one of many momenta

Electron Configuration

Schrodinger's equation questions:

1. We know quantum particles can occupy more than one state at the same time because:
   a. We find particles confined to a small region of space
   b. We see particles with well-defined momentum
   c. We see electrons interfering after passing through a double slit
   d. We see cats that are both alive and dead

2. We see wave behavior in electrons but not in cats because:
   a. Electrons move much faster than cats
   b. Electrons move much slower than cats
   c. Electrons are easier to control than cats
   d. Electrons have much lower mass than cats

3. An electron in the vicinity of two nearby atoms will be orbiting:
   a. The heavier of the two atoms only
   b. The lighter of the two atoms only
   c. Only one of the two atoms, but it's impossible to know which
   d. Both of the two atoms at the same time

Electron Configuration

Schrodinger's equation questions:

4. The behavior of electrons moving through solid objects is determined by:
   a. Electrons bouncing off atoms in the solid like billiard balls
   b. Electrons going around the outside of the solid like waves
   c. Electrons being shared between all of the atoms in the solid
   d. Electrons being pushed through the solid by other electrons

5. Quantum physics is important for computer technology because:
   a. The sharing of electrons between atoms determines the properties of semiconductors
   b. Internet messages are sent using the wave properties of electrons
   c. The flow of electrical current can only be understood in terms of waves
   d. The bits in a modern computer use single electrons

Electron Configuration

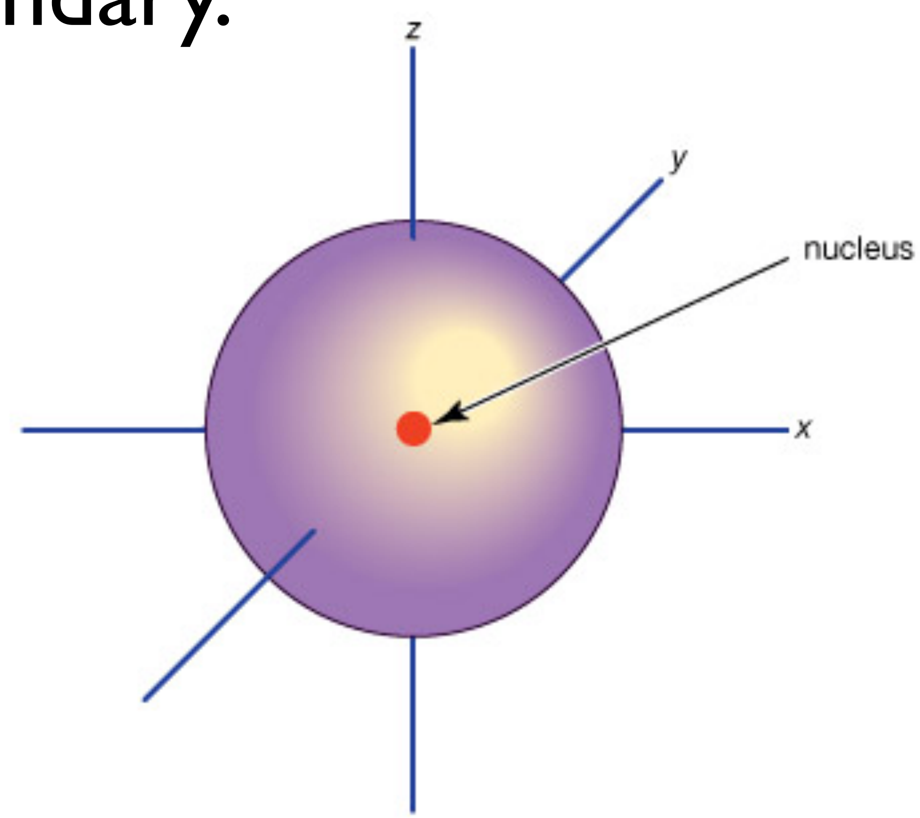
Schrodinger and atomic orbitals

- Schrodinger's work led to a series of mathematical functions called **wavefunctions** describing the electron in the hydrogen atom and associated possible energy states the electron can occupy.
  - Ψ represents wave function and Ψ^2 represents the probability of finding an electron in a region of space at a given point in distance, *r*, from the nucleus. Known as **probability density**
- An **atomic orbital** is a region in space where there is a high *probability* of finding an electron.
  - Can hold a *maximum* of two electrons, with opposite spins
  - Types of orbitals: *s, p, d, f* ***(for SL only need to know s and p orbital shape)***
  - Each has a characteristic *shape* and associated *energy*

Electron Configuration

The atomic orbitals

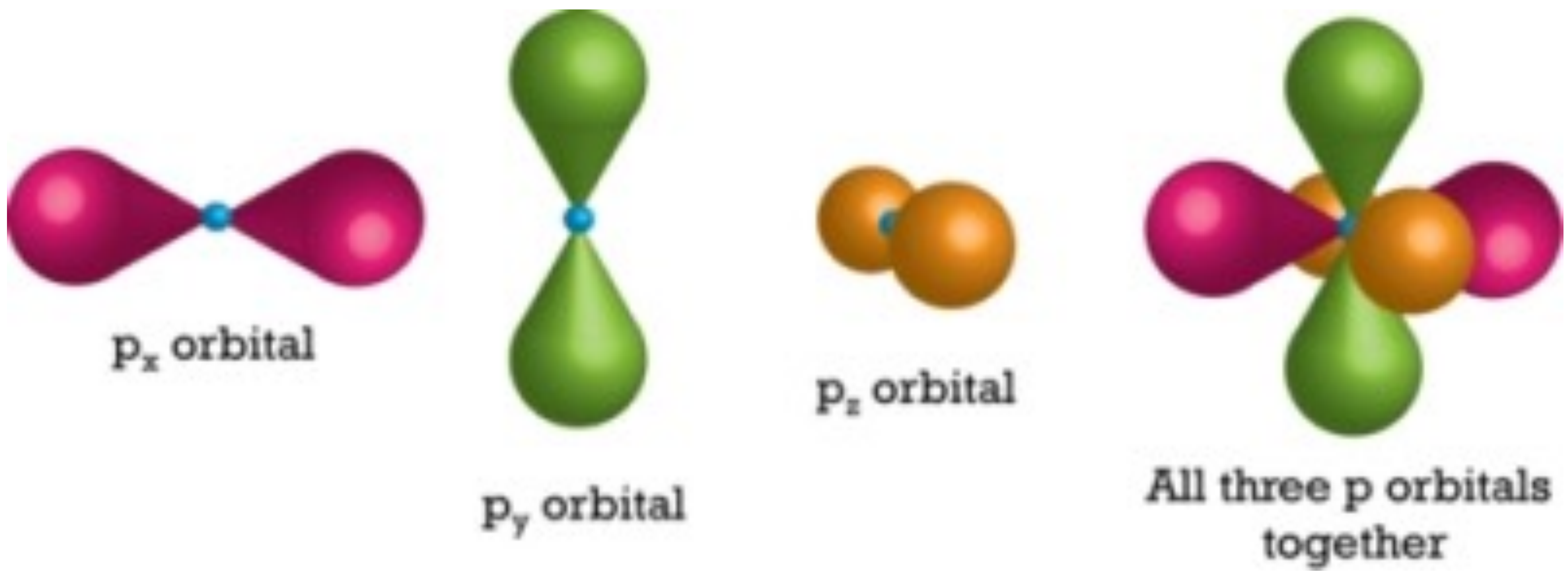
- **The s atomic orbital**
  - Spherically symmetrical
  - 99% chance of probability of finding an electron within the spherical boundary.



Electron Configuration

The atomic orbitals

- **The p atomic orbital**
  - Dumbbell shaped
  - Three p atomic orbitals p_x, p_y, p_z all with boundary surfaces conveying probable electron density pointing in different directions along the three respective Cartesian axes x, y, and z.



Electron Configuration

The atomic orbitals

- **Energy levels, sublevels, orbitals, and electron spin**
  - **Principal quantum numbers**: *n*, energy levels *(1, 2, 3, 4, ...)*
  - As *n* increases, the mean position of the electron is further from nucleus, therefore, orbital energy increases as *n* increases.
  - Each can hold to a max of two electrons given by $2(n)^2$
  - Electron capacity for n=1 is 2, n=2 is 8, for n=3 is 18.
  - On periodic table:
    - Row 1 contains two elements
    - Row 2 contains eight elements
    - Row 3 contains eight elements
    - Row 4 contains 18 elements

Electron Configuration

The atomic orbitals

- **Energy levels, sublevels, orbitals, and electron spin**
    - Energy levels are split into **sublevels**, which there are four common types: *s*, *p*, *d*, and *f*.
    - Each sublevel contains a number of orbitals, each of which can hold a max of two electrons

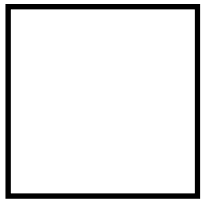
Sublevel	Number of orbitals in sublevel	Maximum number of e^- in sublevel
s	1	2
p	3	6
d	5	10
f	7	14

Electron Configuration

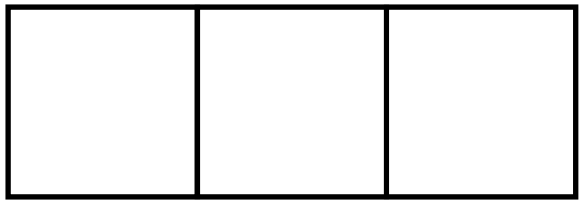
Orbital diagrams

Used to represent the electrons in these atomic orbitals. *We will use these orbital diagrams to represent electron configurations!!!*

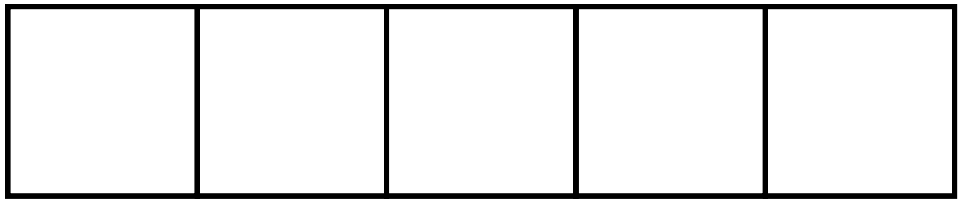
s sublevel (one box represents s orbital)



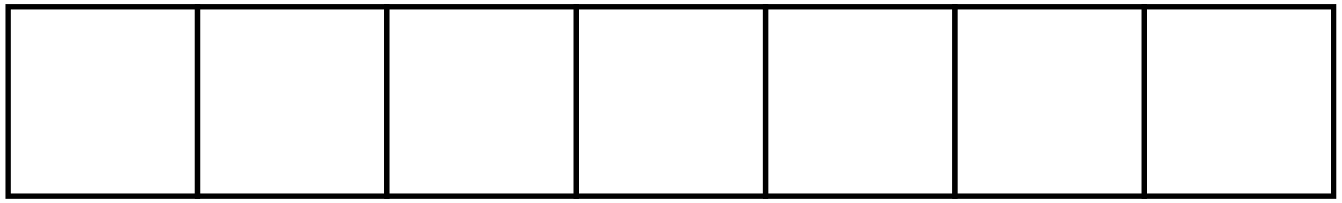
p sublevel (three boxes represents the three p orbitals)



d sublevel (five boxes represents the five d orbitals)



f sublevel (seven boxes represents the seven f orbitals)



Electron Configuration

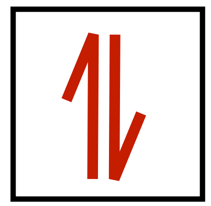
Orbital diagrams

Two electrons in same orbital will have opposite spin values of the spin **magnetic quantum number, m_s**.

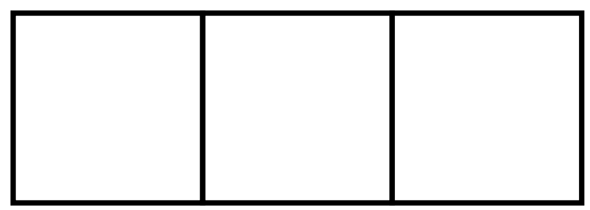
The sign of m_s (+1/2 or -1/2) indicates the orientation of the magnetic field generated by the electron

Electrons behave like two magnets facing opposite directions and is represented by two opposite arrows in a box.

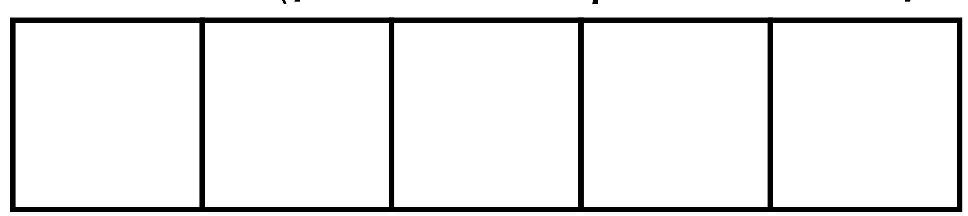
s sublevel (one box represents s orbital)



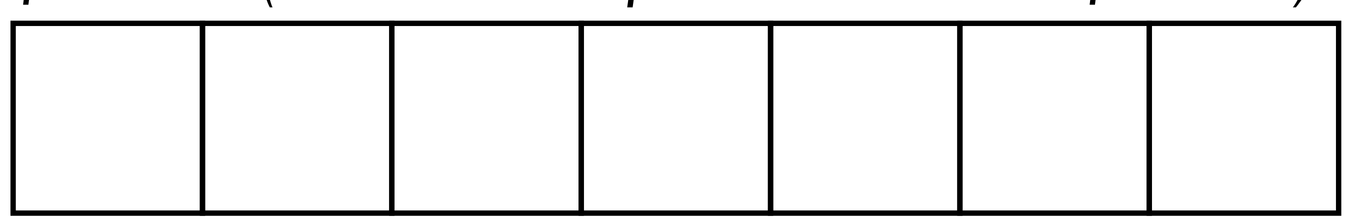
p sublevel (three boxes represents the three p orbitals)

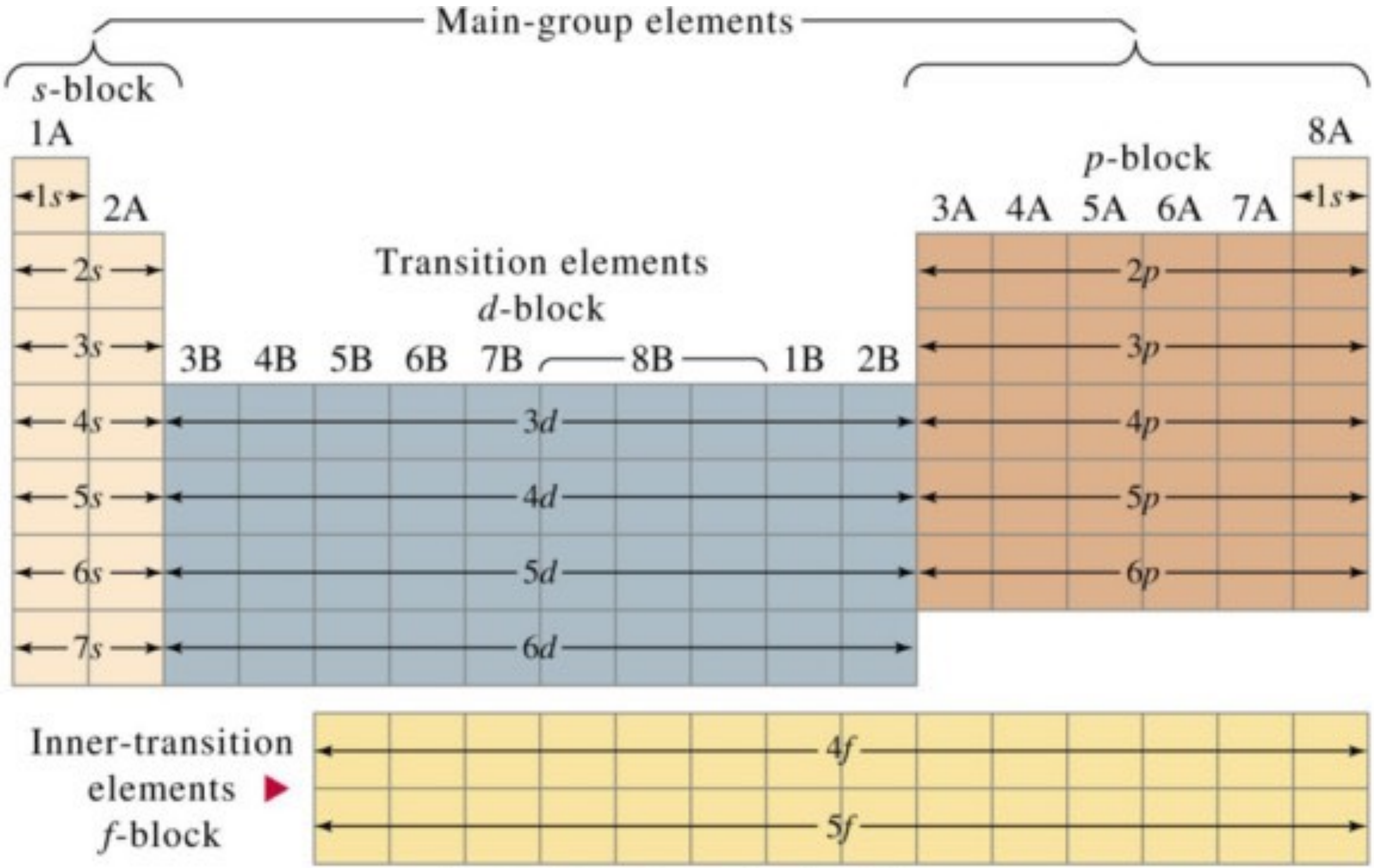


d sublevel (five boxes represents the five d orbitals)



f sublevel (seven boxes represents the seven f orbitals)

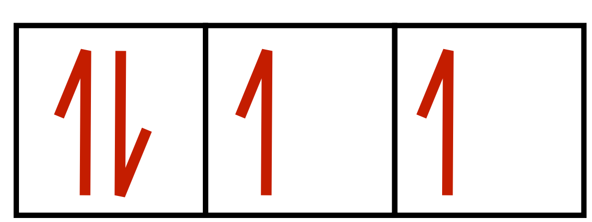



Main-group elements
s-block
1A
1s
2A
8A
p-block
1s
3A 4A 5A 6A 7A
Transition elements
d-block
2s
2p
3s
3B 4B 5B 6B 7B 8B 1B 2B
3p
4s
3d
4p
5s
4d
5p
6s
5d
6p
7s
6d
Inner-transition
elements
f-block
4f
5f

Electron Configuration

Aufbau principle

- Electrons will fill from the *lowest-energy orbital* that is available first.
- Works up to Ca (Z=20) after that Sc (Z=21), the d orbital fills before the s and p orbitals since it is lower in energy.
- **Electron configuration for Ca (Z=20)**
  - $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2$
- **Electron configuration for Sc (Z=21)**
  - $1s^2, 2s^2, 2p^6, 3s^2, 3p^6,$ **$3d^1$**$, 4s^2$ ⟵ *notice the d orbital is filled before the s orbital*
- The **Pauli Exclusion Principle** states that any orbital can hold a maximum of two electrons, and these electrons have opposite spin.
- **Hund's rule of maximum multiplicity** states that when filling **degenerate** orbitals (orbitals of equal energy) electrons fill all the orbitals singly before occupying them in pairs.



2p

Electron Configuration

Full electron configuration for first 36 elements

- Three ways to illustrate electron configuration:
  - *full electron configuration*
  - *condensed electron configuration*
  - *orbital diagram representation*
- Use "build up" method

Element	Z	Electron configuration
Period 1 elements:		
H	1	$1s^1$
He	2	$1s^2$
Period 2 elements:		
Li	3	$1s^22s^1$
Be	4	$1s^22s^2$
B	5	$1s^22s^22p^1$
C	6	$1s^22s^22p^2$
N	7	$1s^22s^22p^3$
O	8	$1s^22s^22p^4$
F	9	$1s^22s^22p^5$
Ne	10	$1s^22s^22p^6$
Period 3 elements: continue with the same filling pattern, for example:		
Na	11	$1s^22s^22p^63s^1$
Mg	12	$1s^22s^22p^63s^2$
Al	13	$1s^22s^22p^63s^23p^1$
Ar	18	$1s^22s^22p^63s^23p^6$
Period 4 elements: After $Z = 30$ the 4p sublevel is filled:		
K	19	$1s^22s^22p^63s^23p^64s^1$
Ca	20	$1s^22s^22p^63s^23p^64s^2$
Sc	21	$1s^22s^22p^63s^23p^63d^14s^2$
Ni	28	$1s^22s^22p^63s^23p^63d^84s^2$
Zn	30	$1s^22s^22p^63s^23p^63d^{10}4s^2$
Ga	31	$1s^22s^22p^63s^23p^63d^{10}4s^24p^1$
Br	35	$1s^22s^22p^63s^23p^63d^{10}4s^24p^5$
Kr	36	$1s^22s^22p^63s^23p^63d^{10}4s^24p^6$

Electron Configuration

Condensed electron configuration

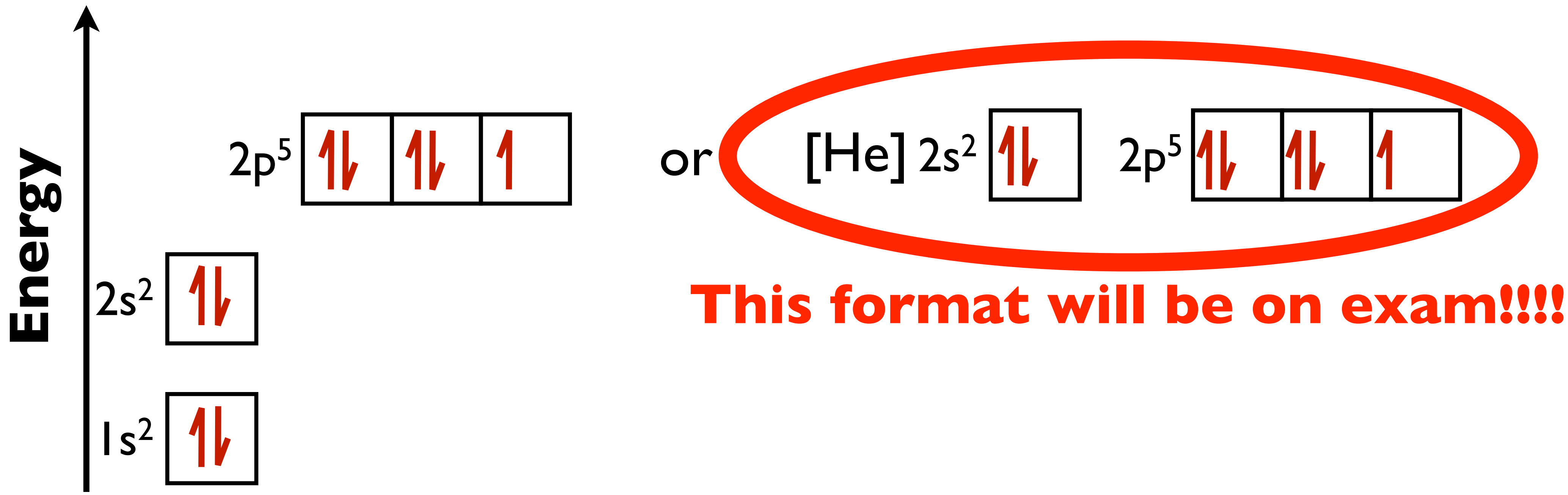
- Full electron configuration can get lengthy so scientists often write in condensed form:
  - [nearest noble gas] + valence electrons
  - Valence electrons are responsible for chemical reactions
- For example:

He	[He]
O	[He] $2s^2$, $2p^4$
Ne	[He] $2s^2$, $2p^6$ or simply [Ne]
P	[Ne] $3s^2$, $3p^3$

Electron Configuration

Orbital diagrams

- **Orbital diagrams** uses the arrows in boxes notation
  - Electrons are represented by arrows ⥮
  - Boxes represent orbitals
  - Degenerate orbitals are joined together to show their energy equivalence
  - Can show full configuration or just from nearest noble gas
  - Fluorine $1s^2, 2s^2, 2p^5$



Practice Problem

... I Do ...

What is the order of increasing energy of the orbitals within a single energy level?

A) d < s < f < p

B) s < p < d < f

C) p < s < f < d

D) f < d < p < s

Practice Problem

... We Do ...

List the following types of electromagnetic radiation in order of **increasing** wavelength (shortest first).

I. Yellow light
II. Red light
III. Infrared radiation
IV. Ultraviolet radiation

b) Distinguish between a continuous spectrum and a line spectrum.

Practice Problem

20 mins

... You Do ...

Work with a partner and answer the following questions:

a) Deduce the full electron configuration for Mn and Mn^{2+}.

b) Deduce the condensed electron configuration for Cu^{2+}.

c) Draw orbital diagrams for Co^{2+} and As.

Topic 2.2
Electron configuration

➡ Emission spectra are produced when photons are emitted from atoms as excited electrons return to a lower energy level.

➡ The line emission spectrum of hydrogen provides evidence for the existence of electrons in discrete energy levels, which converge at higher energies.

➡ The main energy level or shell is given an integer number, n, and can hold a maximum number of electrons, $2n^2$.

➡ A more detailed model of the atom describes the division of the main energy level into s, p, d and f sub-levels of successively higher energies.

➡ Sub-levels contain a fixed number of orbitals, regions of space where there is a high probability of finding an electron.

➡ Each orbital has a defined energy state for a given electronic configuration and chemical environment and can hold two electrons of opposite spin.