Unit 2 - Atomic Structure

Relative Atomic Mass, Electron Configuration, Electrons in Atoms

Question

- Which of the following contains more electrons than neutrons?
  - H-2
  - B-11
  - $[O\text{-}16]^{2-}$
  - $[F\text{-}19]^{1-}$

Finding Relative Atomic Mass

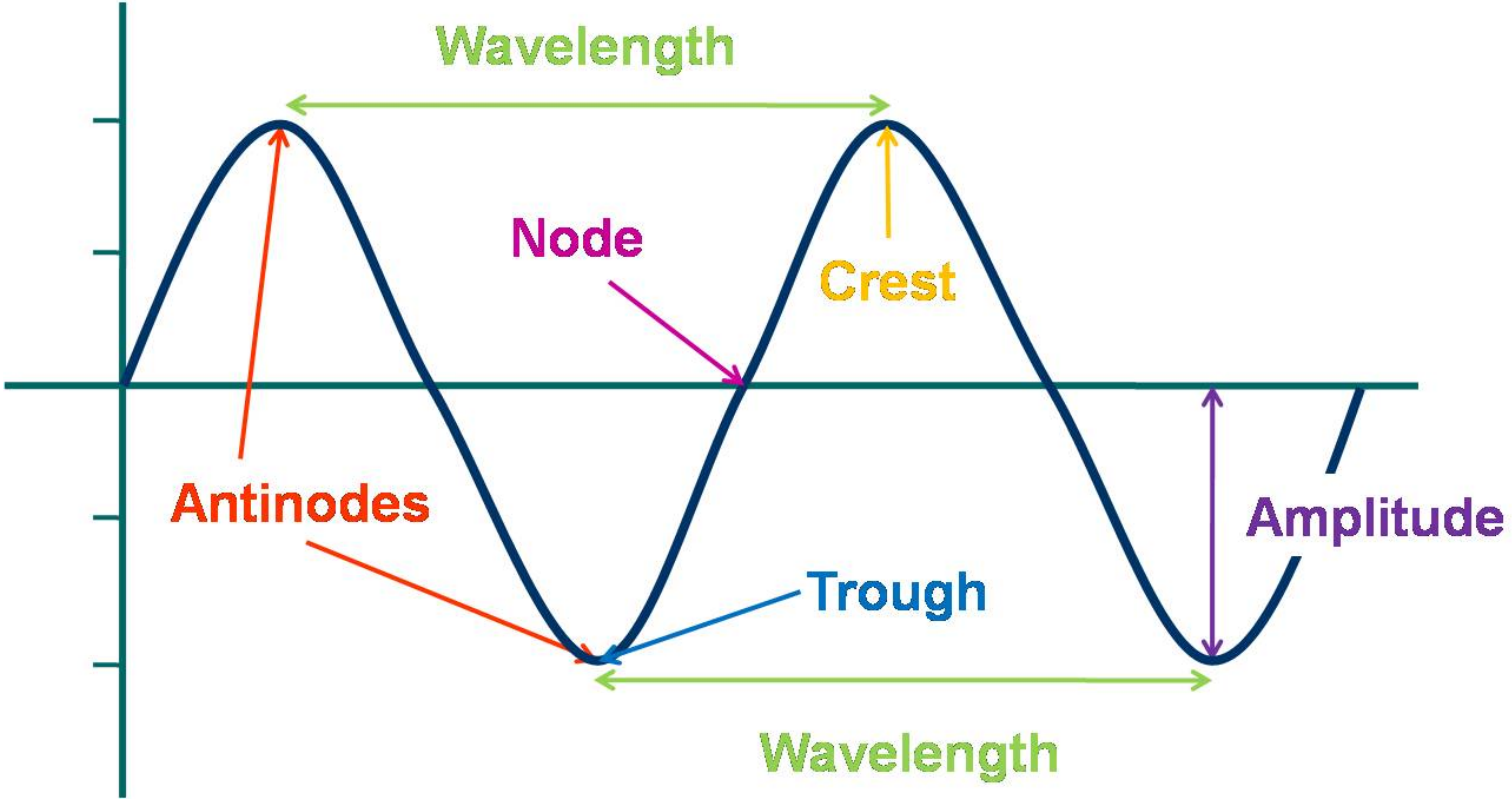
Find the relative atomic mass of Rubidium if 77% of the sample is Rb-85 and 23% of the sample is Rb-87.

Finding Relative Abundance

Boron exists in two forms B-10 and B-11. Use your periodic table to find the abundances of the two isotopes.

Electromagnetic Spectrum

- Do we know how fast EM waves travel?
- Do they all travel at the same speed?
- How do we distinguish them?
- # of waves that pass a point in 1 sec is called _______________
- Are these 3 quantities (speed, distinguishing between, #/sec) related?



Wavelength
Node
Crest
Antinodes
Amplitude
Trough
Wavelength

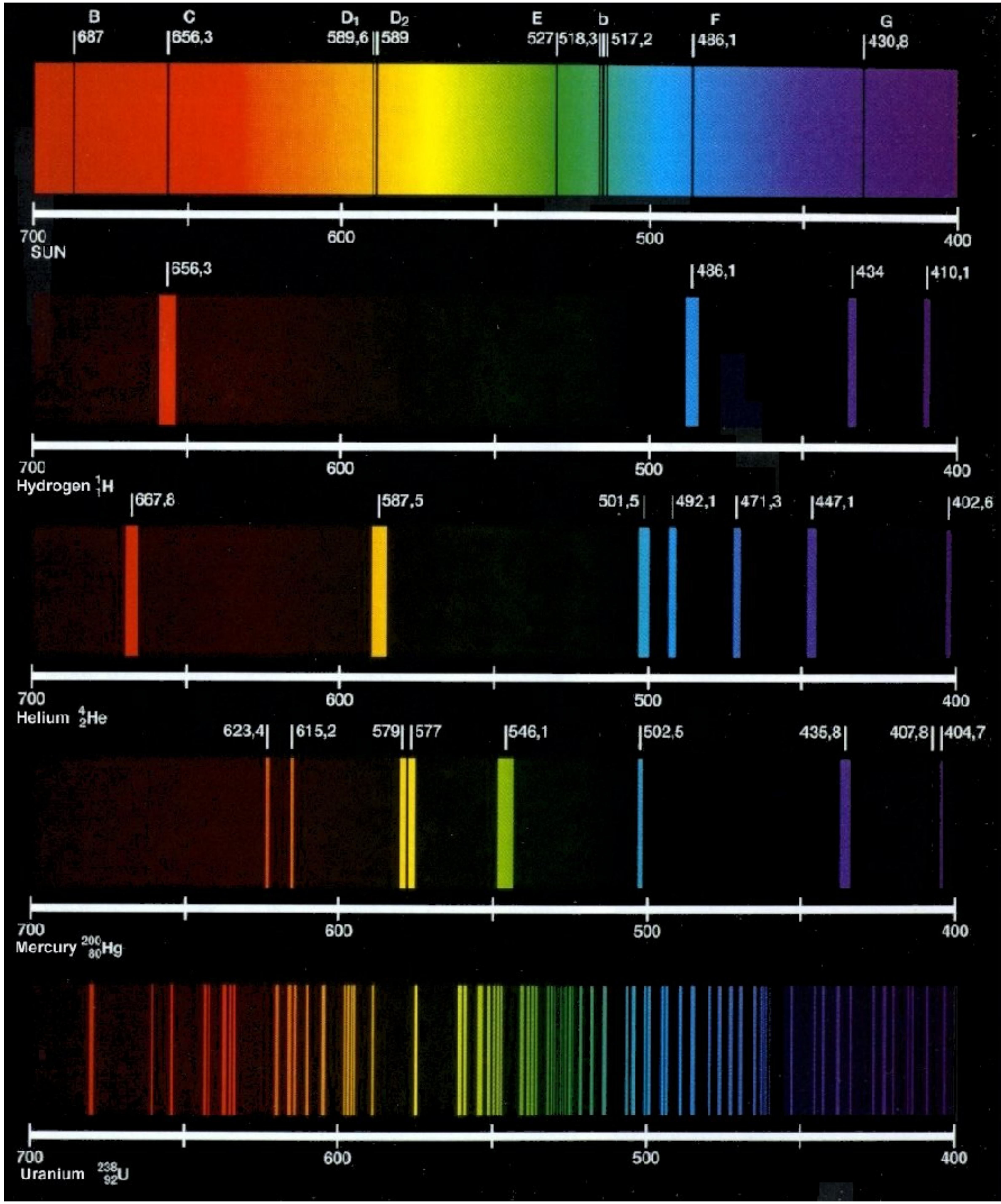
Electromagnetic Spectrum

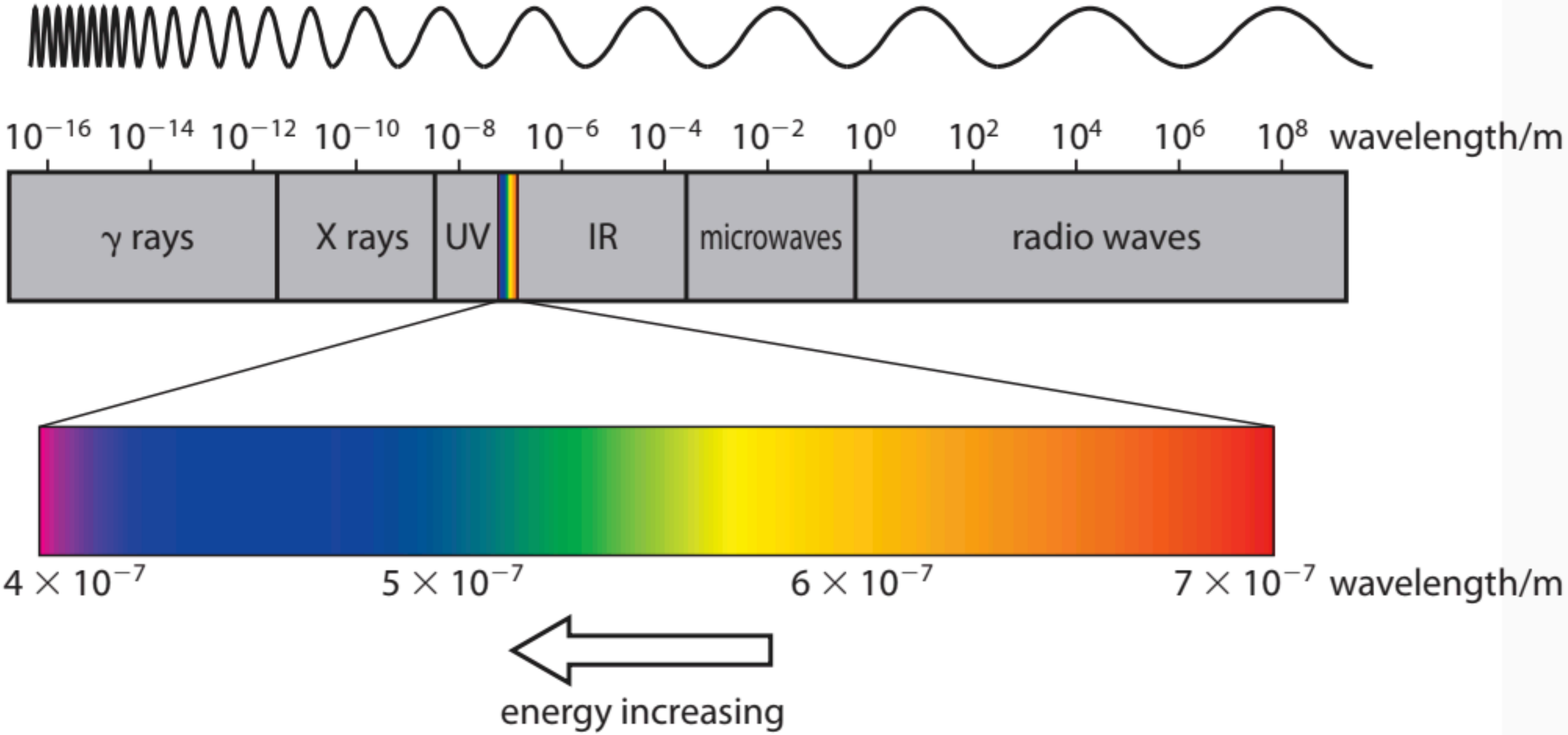
$c = v\lambda$

c = speed of light (3.00×10^8 m•s^{-1})

v = frequency (waves / second)

λ = wavelength (nm)



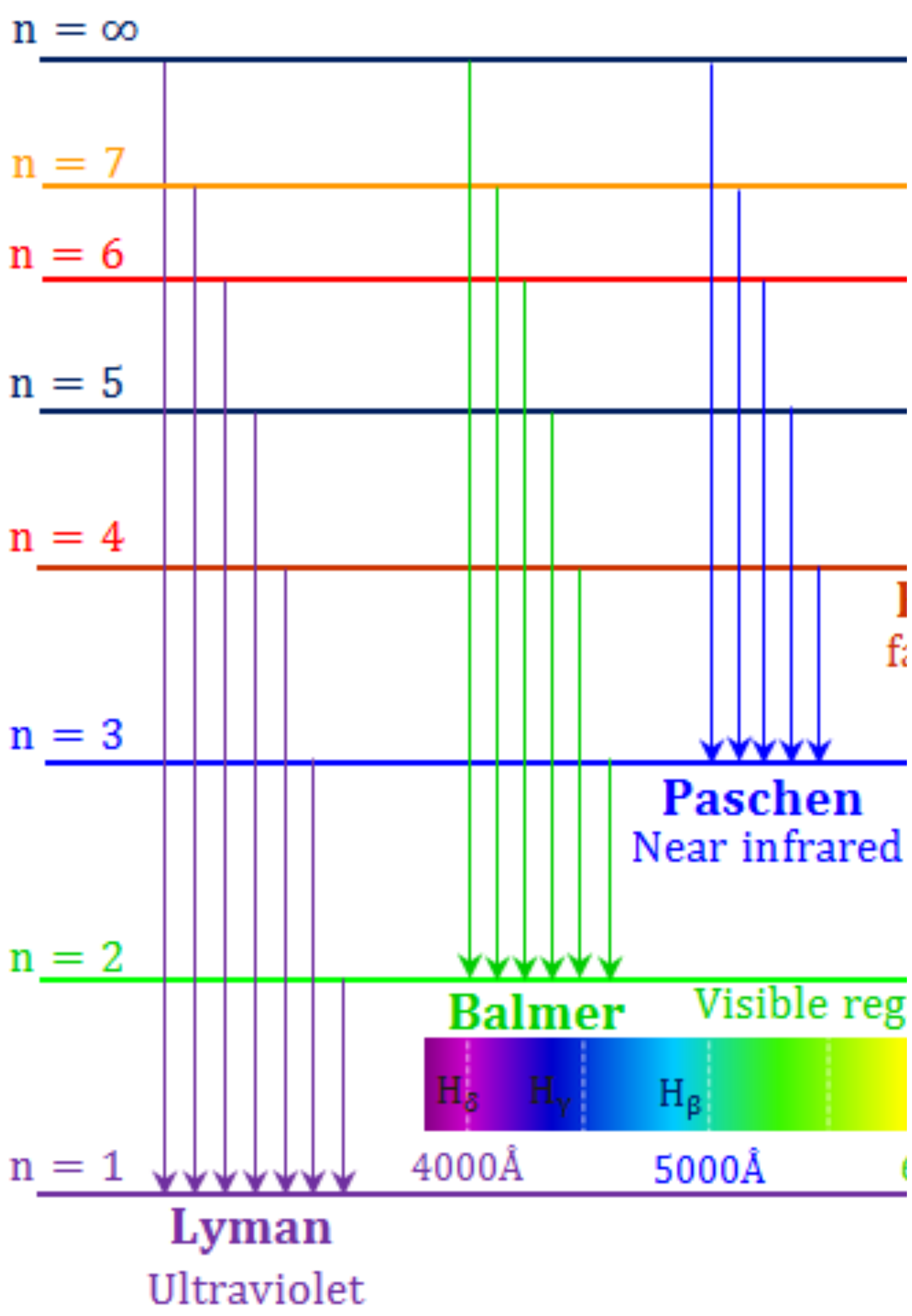


10^{-16} 10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 10^{0} 10^{2} 10^{4} 10^{6} 10^{8} wavelength/m
γ rays
X rays
UV
IR
microwaves
radio waves
4×10^{-7} 5×10^{-7} 6×10^{-7} 7×10^{-7} wavelength/m
energy increasing

Evidence for the Bohr Model

- How can hydrogen emit AND absorb energy?
- Excited State vs. Ground State
- One packet of energy (quantum) or photon is released for every transition
- The energy E_{photon} of light, is related to its frequency, v, by Planck's constant
    - $E_{photon} = hv$
    - $h = 6.63 \times 10^{-34}$ J s
- Equations found on Table 1 and constants found on Table 2

The Hydrogen Spectrum



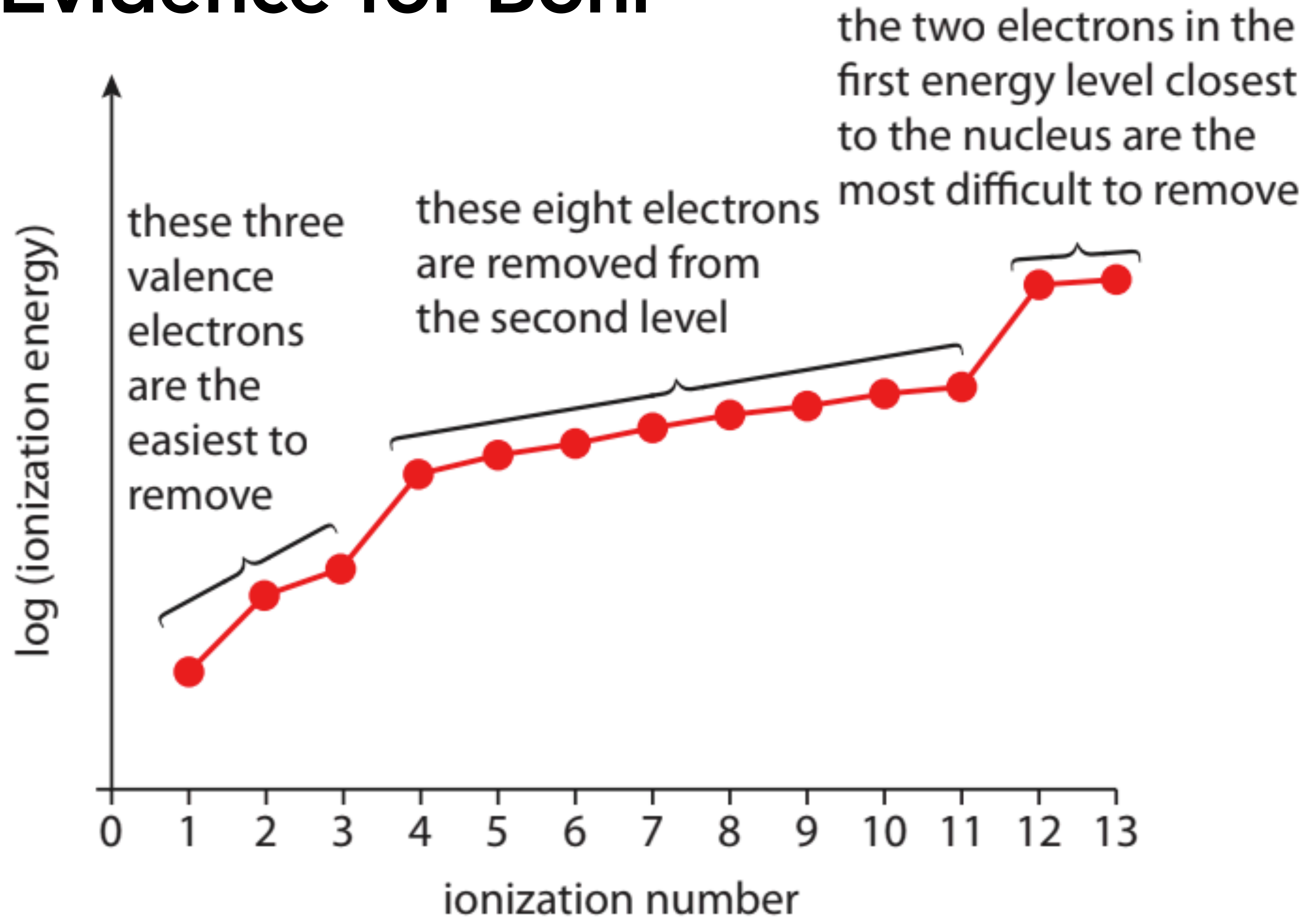
Ionization Energy

- the energy needed to remove an electron from the ground state of each atom in a mole of ***<u>gaseous</u>*** atoms, ions or molecules
- can have multiple ionization energies (1st, 2nd, 3rd, etc.)
- 1st: $Al(g) \rightarrow Al^{+}(g) + e^{-}$
- 2nd: $Al^{+}(g) \rightarrow Al^{2+}(g) + e^{-}$
- the pattern will continue for each successive ionization energy

Bohr Model

Draw a Bohr model for the element lithium…

More Evidence for Bohr



What does the graph show?

- Increase in energies for each electron you remove from an atom/ ion
- The jumps in energies take place when you begin taking electrons from an inner electron shell (closer to the nucleus - more exposed to + protons)

How much do you know?

- Which is not a valid electron arrangement?

    A. 2-8

    B. 2-3

    C. 2-7-2

    D. 2-8-8-1

How much do you know?

Deduce the electron arrangement of Na^{+} and O^{2-}

Sub-Levels of Electrons

the n^{th} energy level of the Bohr atom is divided into n sub-levels

Principle Energy Level	Sub-level	Max # of electrons in sub-level	Max # of electrons in level
n=1	1s	2	2
n=2	2s	2	8
	2p	6	
n=3	3s	2	18
	3p	6	
	3d	10	
n=4	4s	2	32
	4p	6	
	4d	10	
	4f	14	

Waves vs. Particles

- light - described by frequency (waves) and energy of individual particles (photons)
  - related by Planck's equation E=hv
- diffraction (spreading out) - wave
- scattering of electrons when light hits a metal surface - particles

SO WHICH IS IT?

The Uncertainty Principle

- Nice try, Bohr....
  - electrons path can be precisely described…not so much
- the act of focusing radiation in an attempt to find an electron would do what???

Heisenberg's Uncertainty Principle

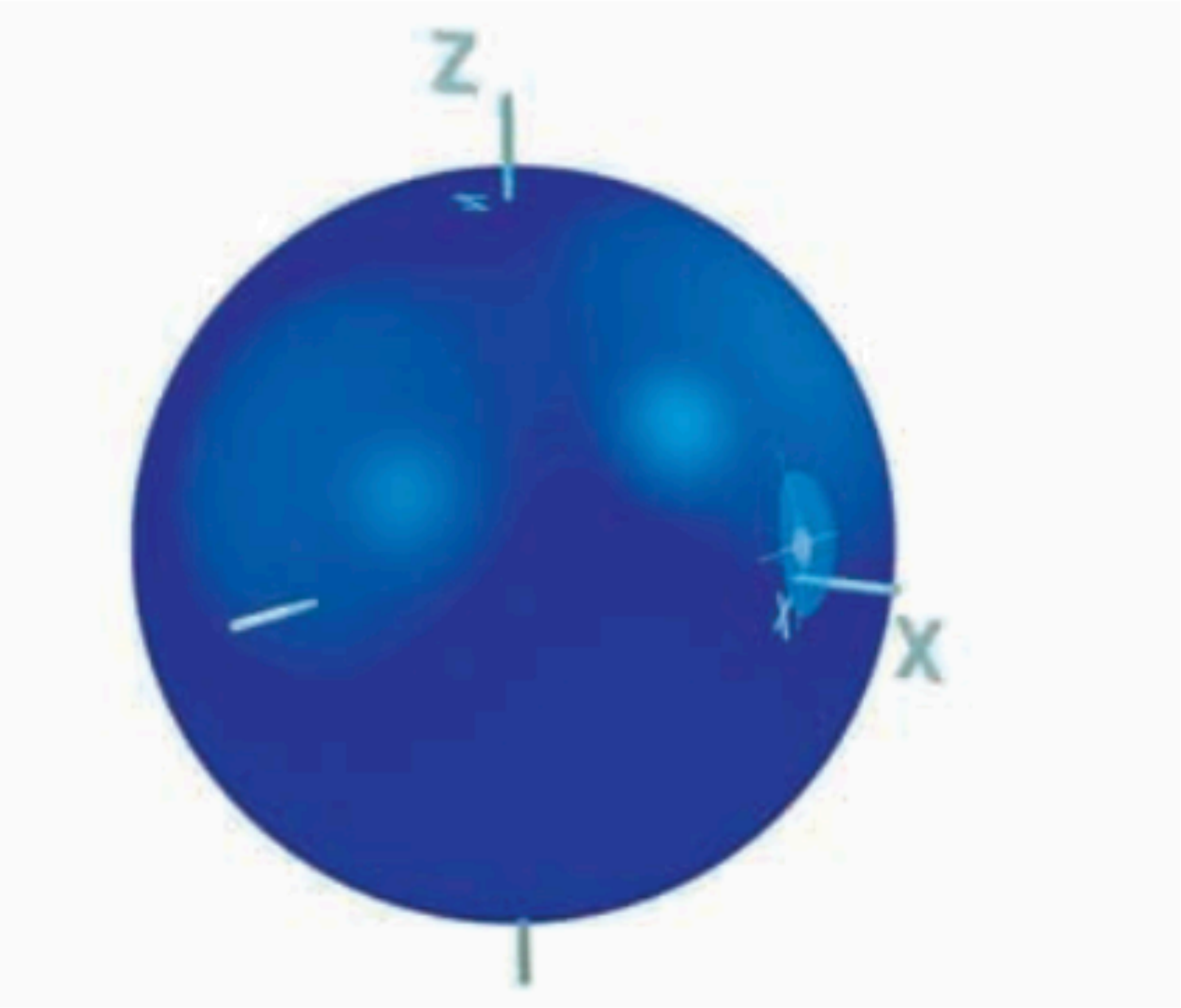
- Cannot make simultaneous measurements to show the position and momentum (speed) of an electron at a given time

Did you know....Niels Bohr and Werner Heisenberg worked together in the early years of Quantum Theory, but found themselves on different sides of WWII when war broke out.

Atomic Orbitals

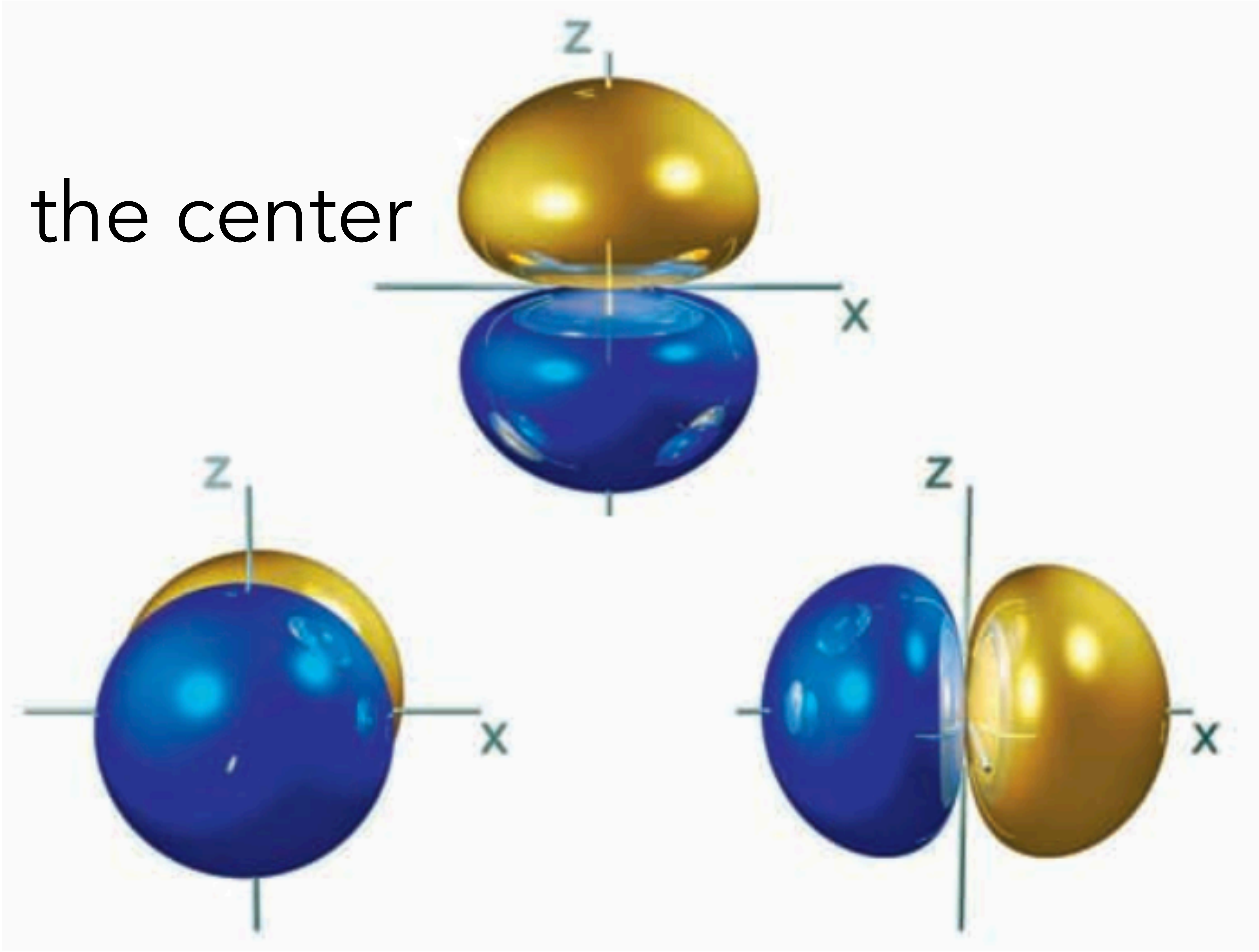
s-Orbitals

- highlights the distinction between the wave and particle descriptions
- 1s orbital is the closest to the nucleus and therefore have the least amount of energy
- 2s - same symmetry over a larger volume



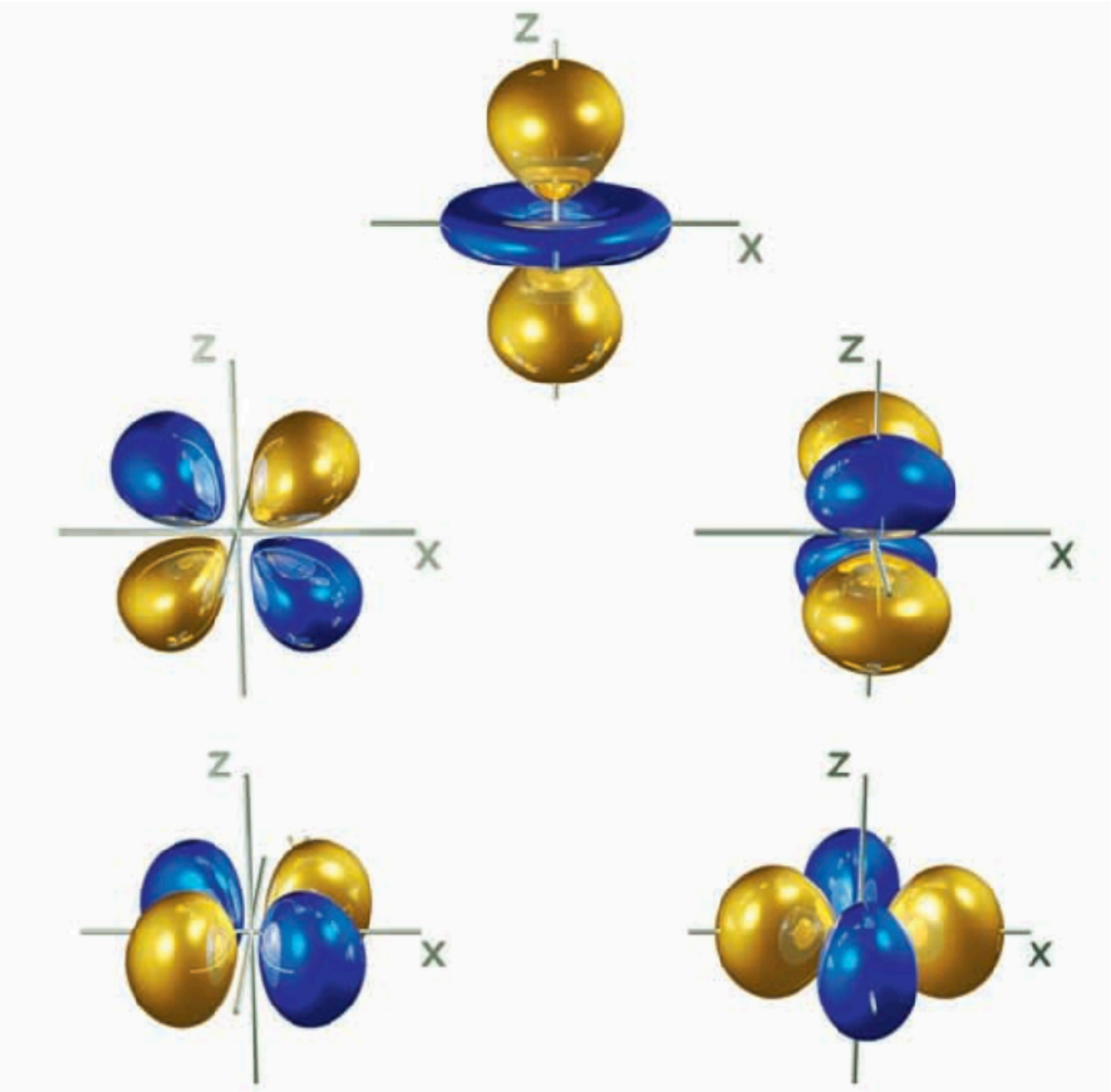
p Atomic Orbitals

- The p sub-levels contain 3 atomic orbitals of equal energy (they call this *degenerate*)
- All have dumbbell shape
- Only difference is orientation in space
- Arranged at right angles with nucleus in the center



d and f orbitals

- d sub-levels have 5 d atomic orbitals
- f sub-levels have 7 f atomic orbitals (the only ones you DON'T have to know)



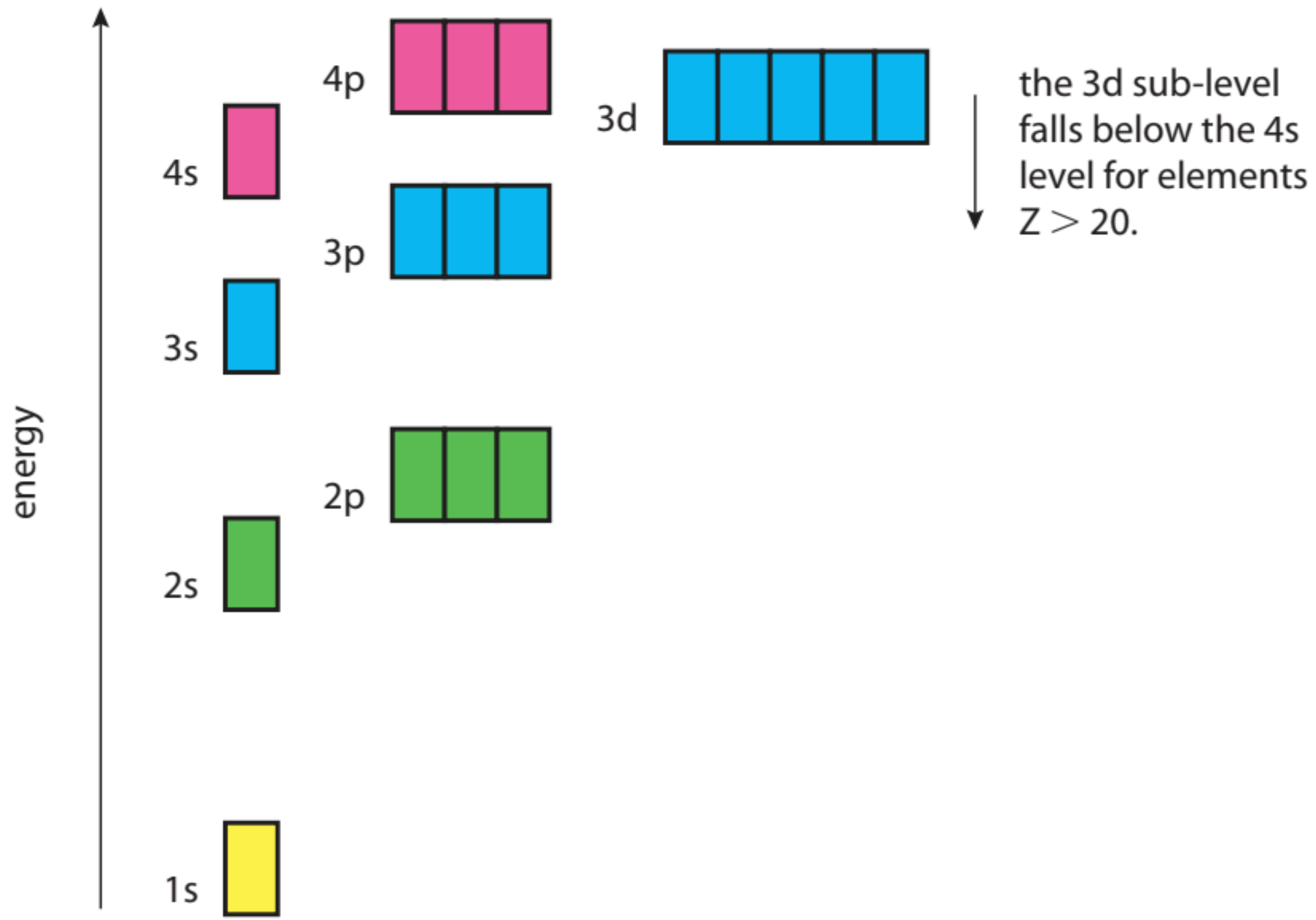
Now…Without your notes…

- Draw a 1s orbital

- Draw a $2p_x$ orbital

Electron Spin and the Pauli Exclusion Principle

- Why do electrons go in to specific orbitals?
- Why do electrons enter the 4s BEFORE the 3d?
- Why don’t electrons in the same orbital repel each other?
- How many electrons actually fit in an orbital?


energy
1s
2s
3s
4s
2p
3p
4p
3d
the 3d sub-level
falls below the 4s
level for elements
Z > 20.

Another question...

- List the 4d, 4f, 4p and 4s orbitals in order of increasing energy
- Ans: 4s, 4p, 4d, and 4f
- State the number of 4d, 4f, 4p and 4s atomic orbitals.
- Ans: 5, 7, 3, 1

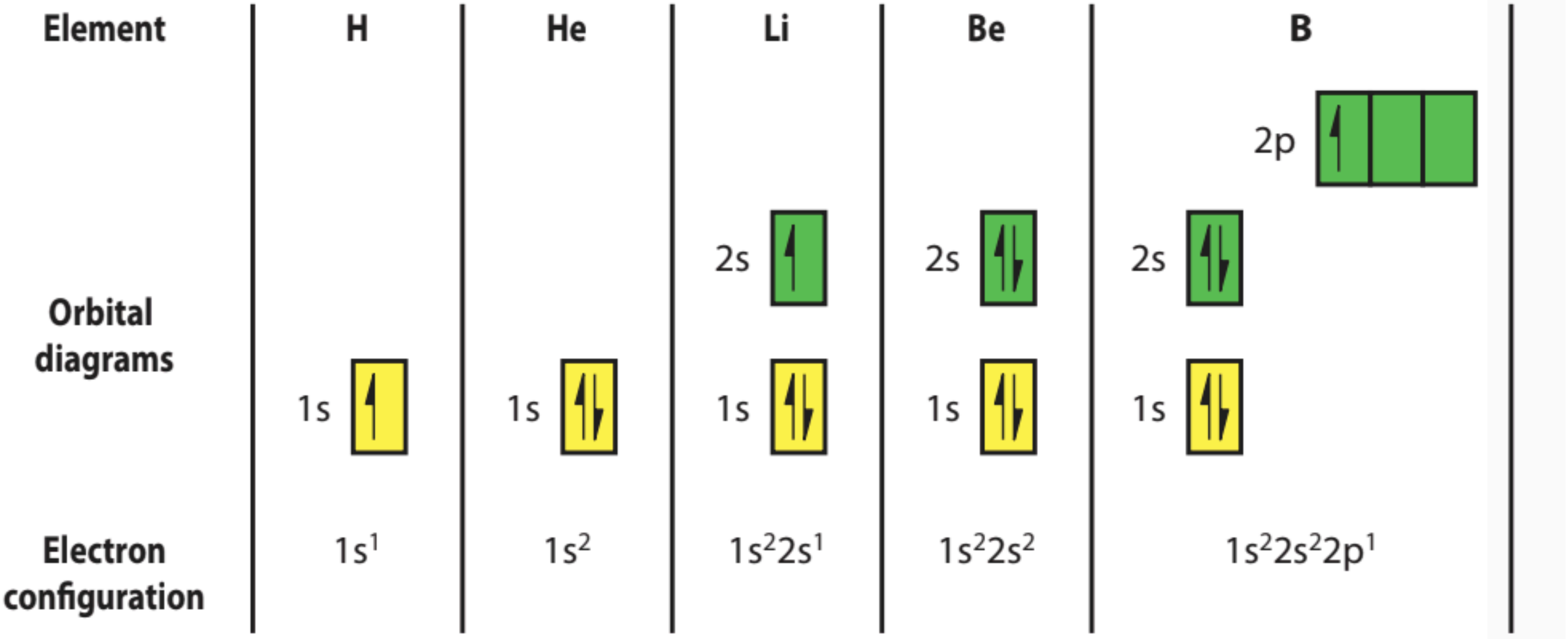
Pauli Exclusion Principle

- No more than 2 electrons in any one orbital!

- If they occupy the same orbital, MUST spin in opposite directions (one clockwise and one counter clockwise)

Aufbau Principle

- electrons are placed into the lowest available energy level first



What happens for Carbon? Where does the next e^- go?

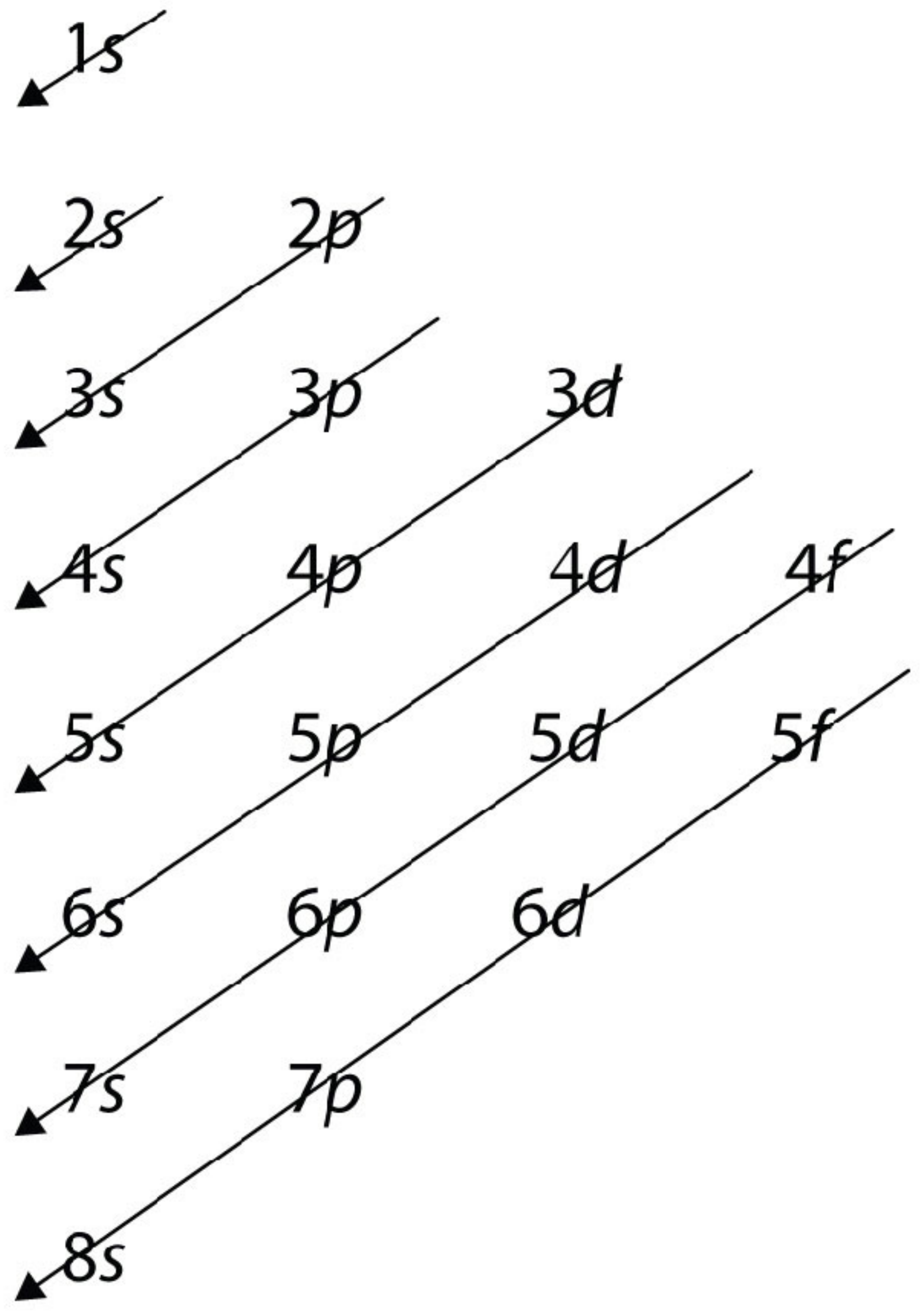
So…What Happens?

- Carbon's next electron can either fill the same orbital or they can be placed in separate p-orbitals
- Hund's 3rd Rule (don't ask me what his 1st or 2nd rule was) - put them in separate orbitals to allow them to minimize the repulsion between them
- Orbitals do not overlap - unlikely to approach each other

What about spin?

- The electrons will have parallel spins because this is found to have lower energy

- Draw electron in a box for Carbon and Nitrogen


1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f
6s 6p 6d
7s 7p
8s

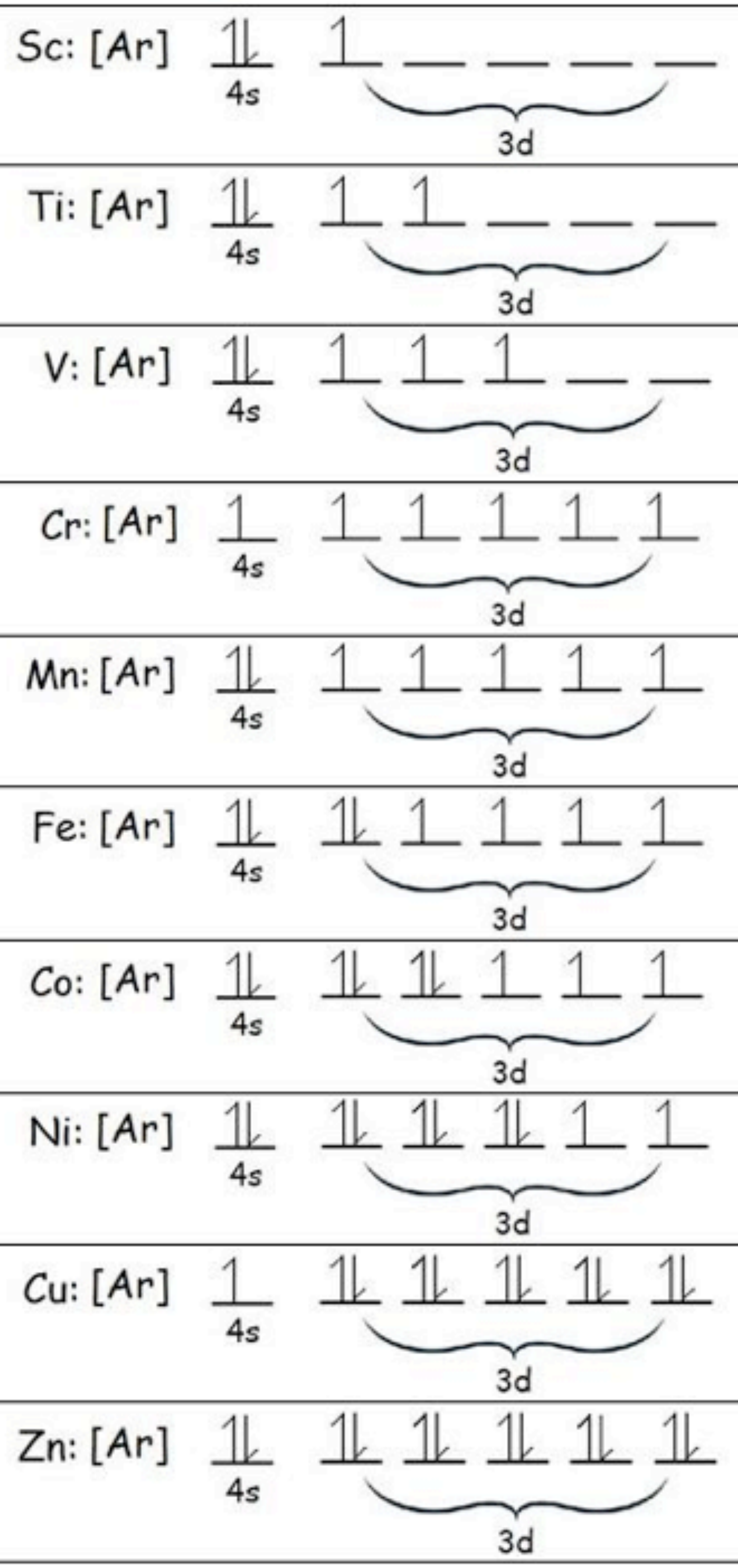
Lets see what you can do…

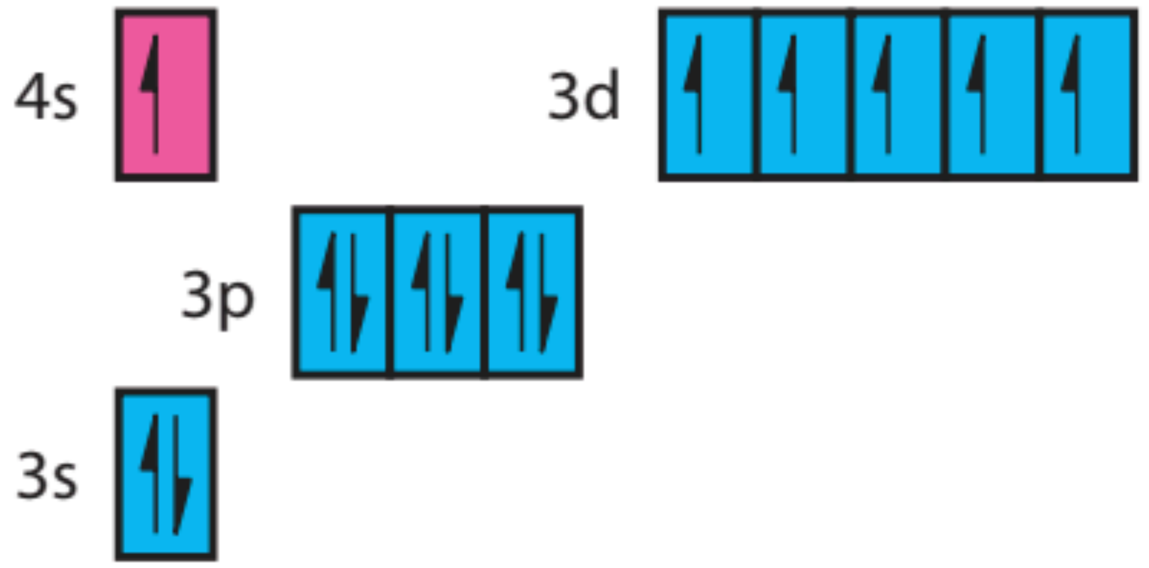
- State the full electron configuration of arsenic and deduce the number of unpaired electrons.

- $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^3$
- The 4p orbitals each have an unpaired e^-
- ans: 3 unpaired electrons

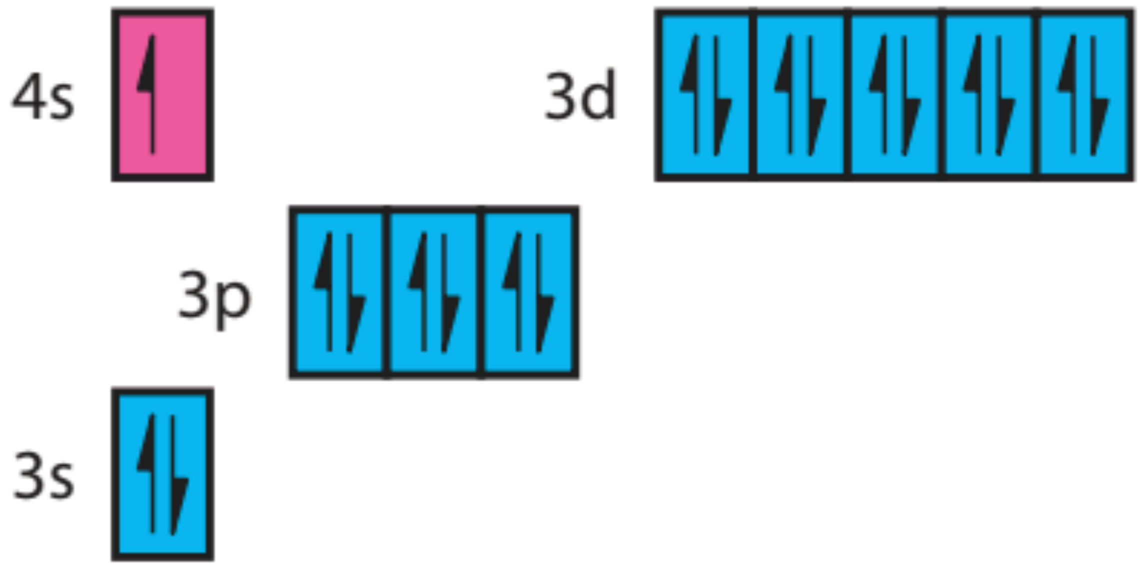
What do you notice with these configurations?

Electron Configuration
Sc: [Ar] $4s^2 3d^1$
Ti: [Ar] $4s^2 3d^2$
V: [Ar] $4s^2 3d^3$
Cr: [Ar] $4s^1 3d^5$
Mn: [Ar] $4s^2 3d^5$
Fe: [Ar] $4s^2 3d^6$
Co: [Ar] $4s^2 3d^6$
Ni: [Ar] $4s^2 3d^7$
Cu: [Ar] $4s^1 3d^{10}$
Zn: [Ar] $4s^2 3d^{10}$





chromium: [Ar]$3d^5 4s^1$



copper: [Ar]$3d^{10} 4s^1$

Practice

- Identify the sublevel which does not exist
    - 5d,   4d,   3f,   2p
- Which is the correct order of orbital filling according to the Aufbau principle?
    - 4s, 4p, 4d, 4f
    - 4p, 4d, 5s, 4f
    - 4s, 3d, 4p, 5s
    - 4d, 4f, 5s, 5p

Practice

- State the full ground-state electron configuration of the following elements.
  - V
  - Se
  - K
  - Sr

Practice

- State the full ground-state electron configuration of the following elements.
  - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$
  - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
  - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$
  - $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 5s^2$

Practice

- Determine the number of electrons in the d orbital of an Iodine atom.

    - 20: 10 in 3d, 10 in 4d

More Practice...

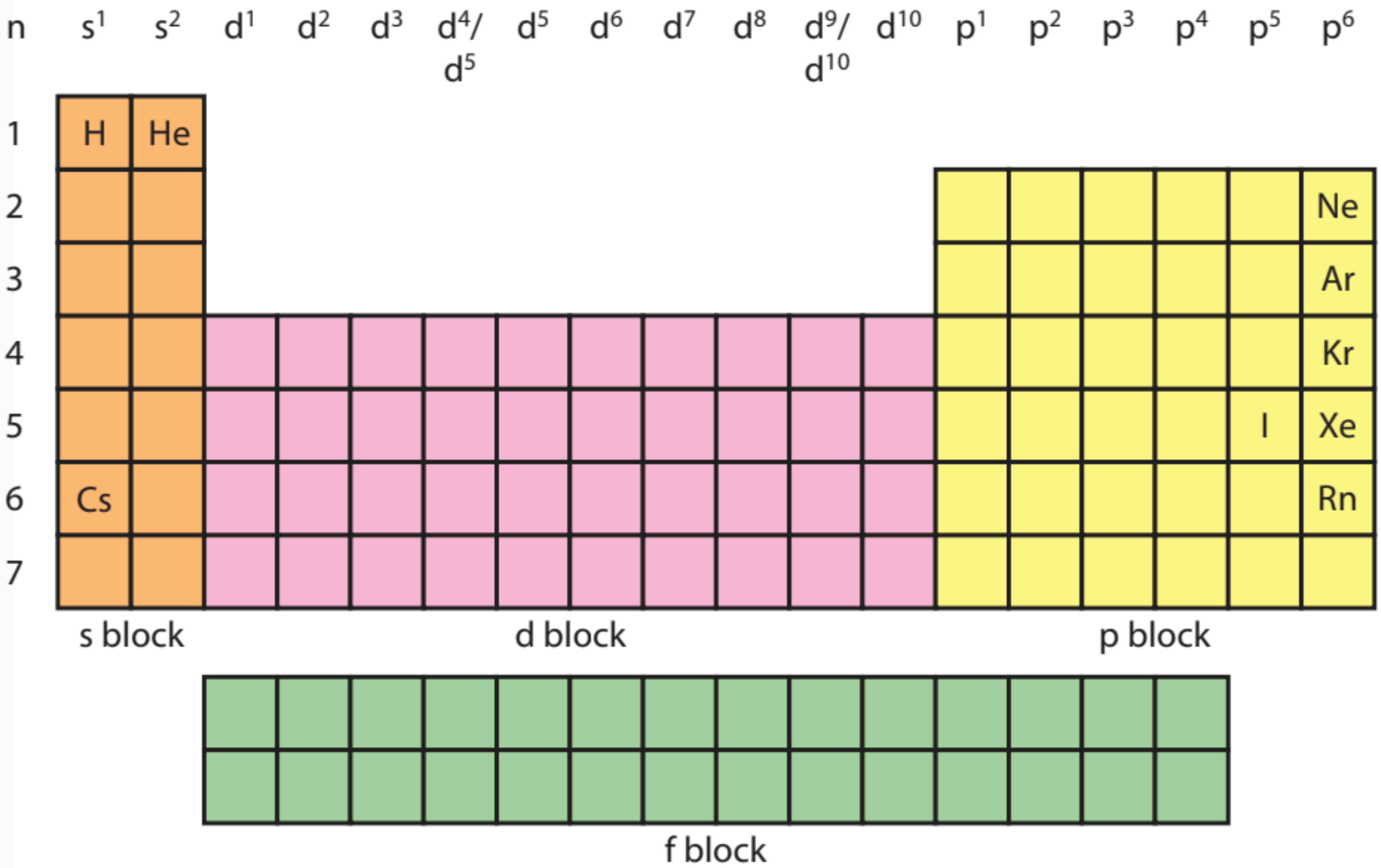
- Deduce the number of unpaired electrons present in the ground state of a titanium atom.

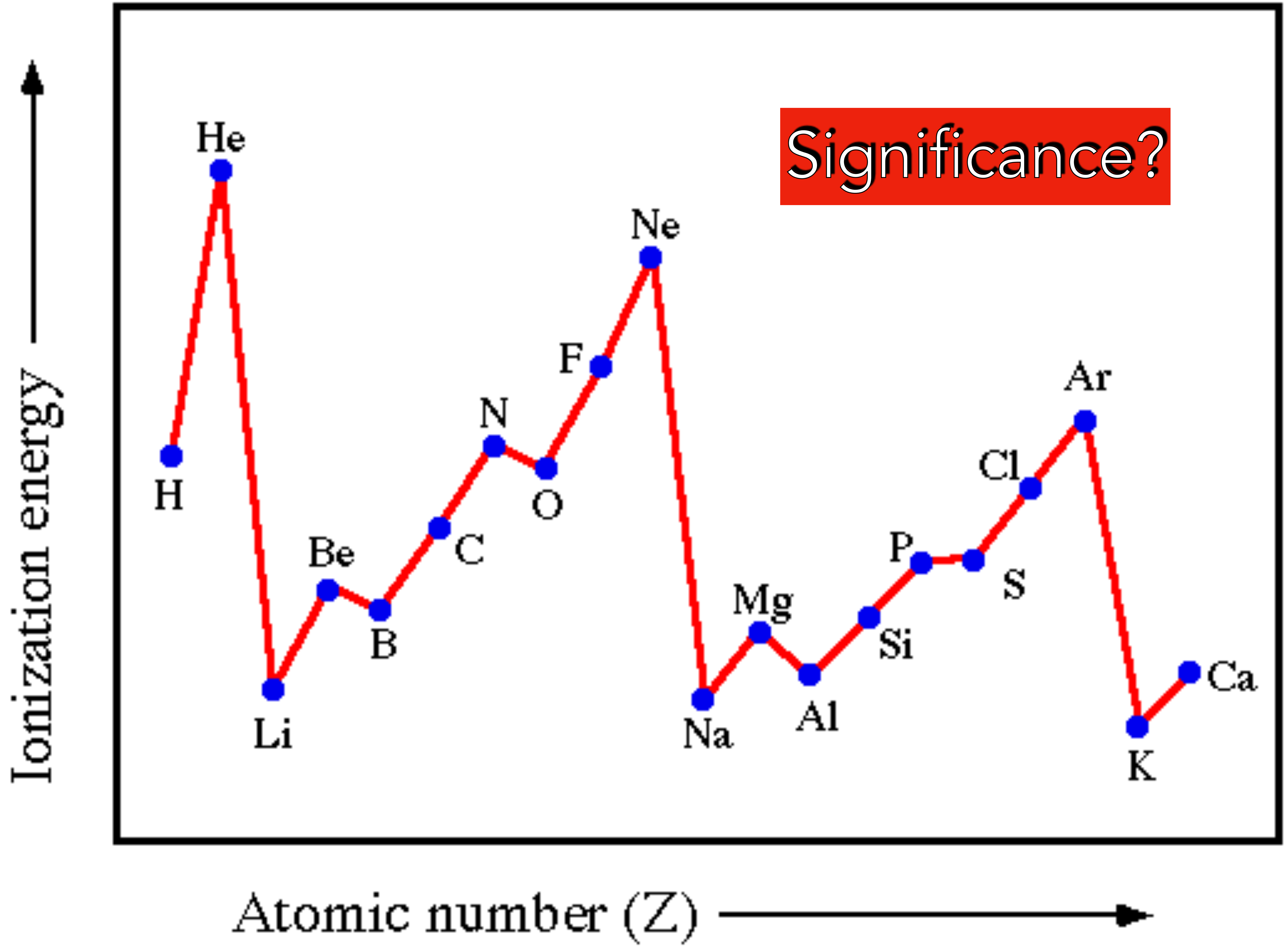
    - 2 - each in 3d sublevel

Electron configurations of Ions

- Using electrons in a box, find the electron configuration of an Al^{5+} ion

- What will be the electron it loses when it becomes a +6 ion?


n
s1
s2
d1
d2
d3
d4/d5
d5
d6
d7
d8
d9/d10
d10
p1
p2
p3
p4
p5
p6
1
2
3
4
5
6
7
H
He
Ne
Ar
Kr
I
Xe
Cs
Rn
s block
d block
p block
f block



Significance?
Ionization energy
Atomic number (Z)
H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Al
Si
P
S
Cl
Ar
K
Ca