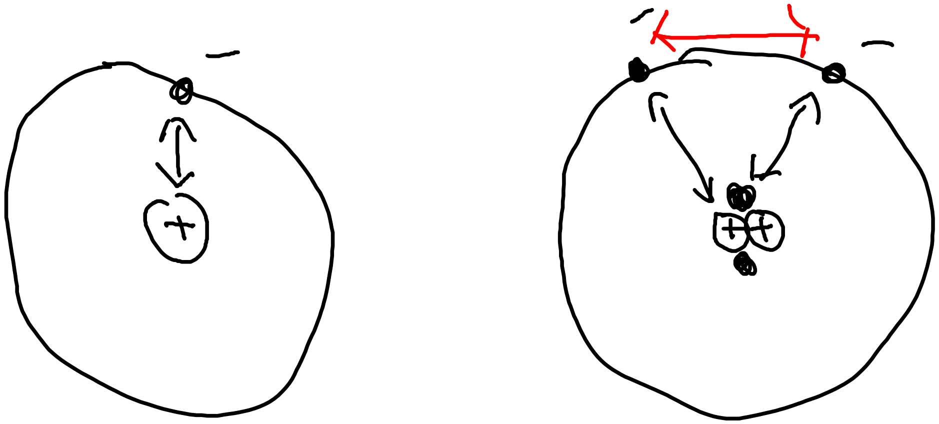


Bohr's model didn't account for electron-electron interactions (which didn't exist in HYDROGEN)

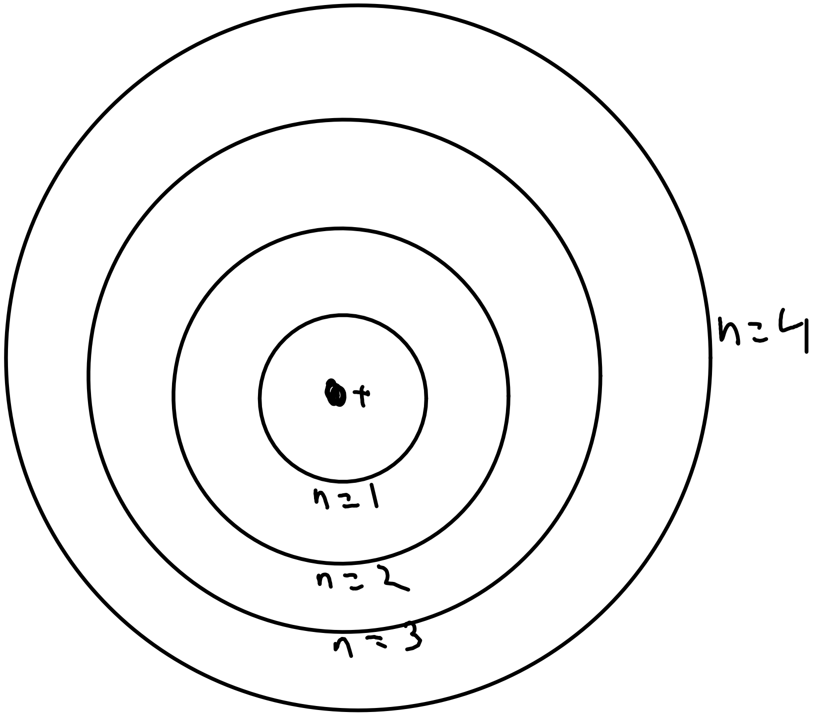
- To account for this added complexity, a more sophisticated model had to be devised: QUANTUM THEORY. Quantum theory is the modern picture of the atom and its electron cloud.

SHELLS, SUBSHELLS, AND ORBITALS

- Bohr's model predicted that energy levels (called SHELLS) were enough to describe completely how electrons were arranged around an atom. But there's more to it!

SHELL: Equivalent to Bohr's energy levels. Electrons in the same SHELL are all the same distance from the nucleus. They all have SIMILAR (but not necessarily the SAME) energy.

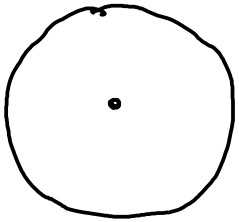
- Shells are numbered (1-... - Elements on the periodic table have shells numbered from 1 to 7)
- Higher numbers correspond to greater distance from the nucleus and greater energy, and larger size!
- Higher shells can hold more electrons than lower shells!



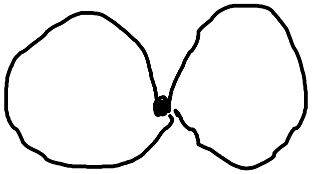
SUBSHELLS: Within a SHELL, electrons may move in different ways around the nucleus! These different "paths" are called SUBSHELLS

- SHAPES of regions of space that electrons are able to exist in.

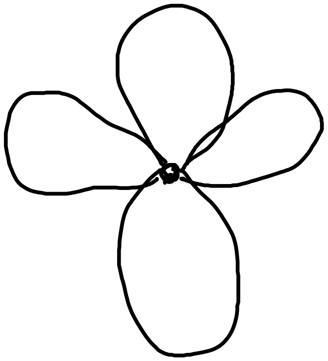
Illustrations:
p315-316



"s" subshell
(a spherical region)



"p" subshell
(a dumbbell shaped region)



"d" subshell

- Some atoms also have "f" subshells (not pictured)

See p 314-316 for nicer f=drawings of the subshells.

ORBITALS - are specific regions of space where electrons may exist

- The SHAPE of an orbital is defined by the SUBSHELL it is in
- The ENERGY of an orbital is defined by both the SHELL the orbital is in AND the kind of SUBSHELL it is in

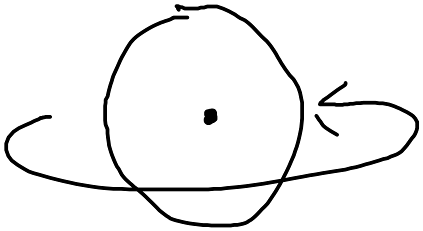
- Each orbital may, at most, contain TWO ELECTRONS

ARRANGEMENT OF SHELLS, SUBSHELLS, AND ORBITALS

- Shells are numbered. Each shell can contain the same number of SUBSHELLS as its number:

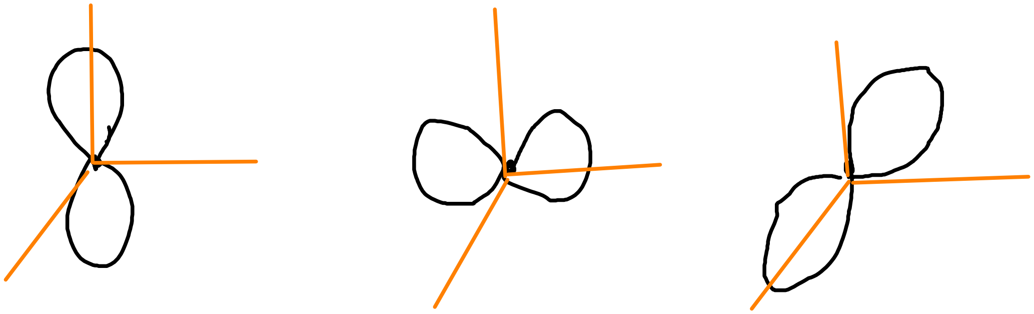
1st shell: ONE possible subshell (s)
2nd shell: TWO possible subshells (s, p)
3rd shell: THREE possible subshells (s, p, d)
4th shell: FOUR possible subshells (s, p, d, f)
... and so on

- Each subshell can contain one or more ORBITALS, depending on how many different ways there are to arrange an orbital of that shape around the nucleus.



"s" subshell
One possible orientation

Maximum 2 electrons in 1 orbital



"p" subshell: Three possible orientations

Maximum 6 electrons in 3 orbitals

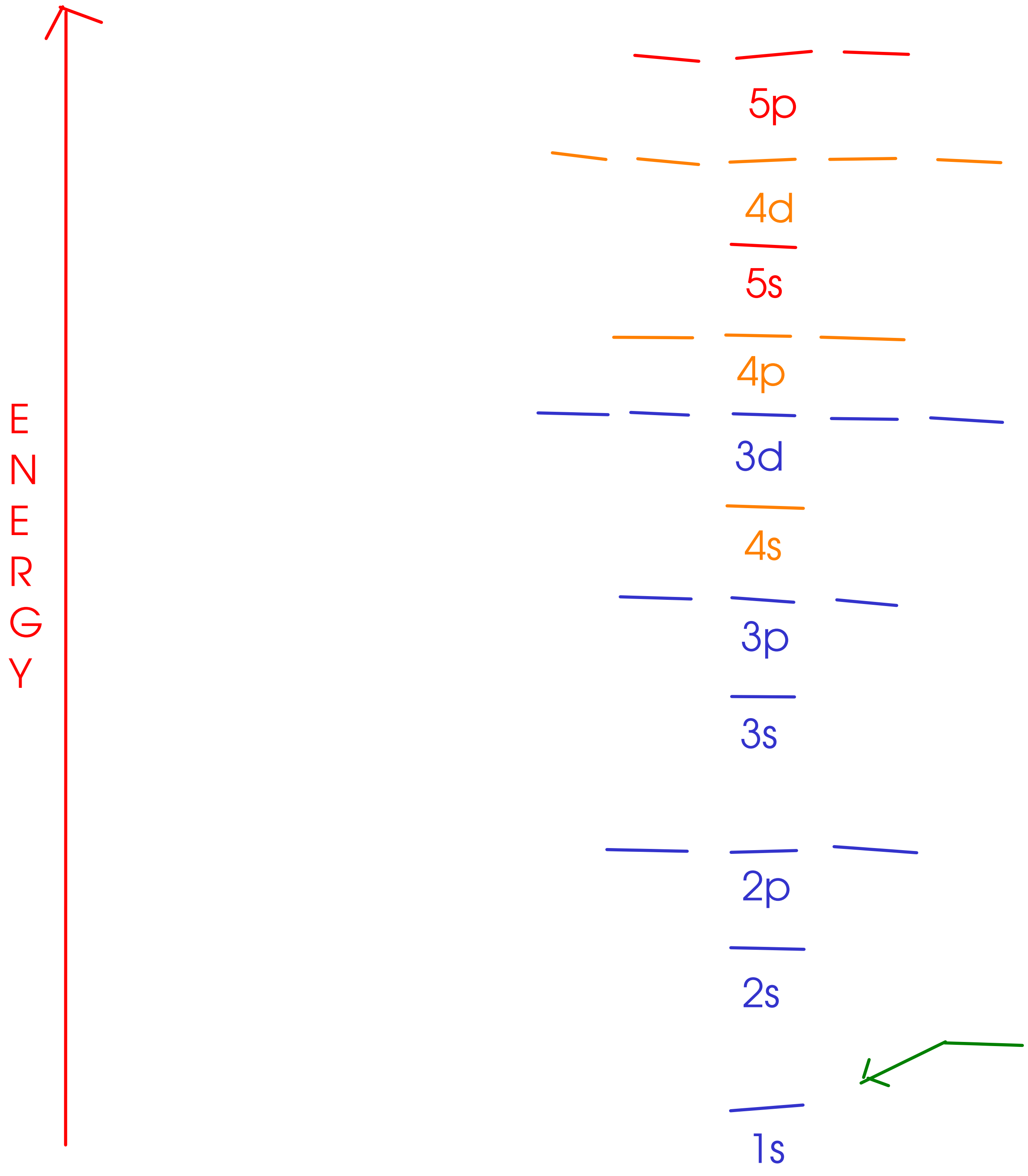
- There are five possible orbitals in a "d" subshell, and 7 possible orbitals in an "f" subshell!

Maximum 10 electrons
in 5 orbitals
(see p 316)

Maximum 14 electrons
in 7 orbitals

ENERGY DIAGRAM

- We can map out electrons around an atom using an energy diagram:



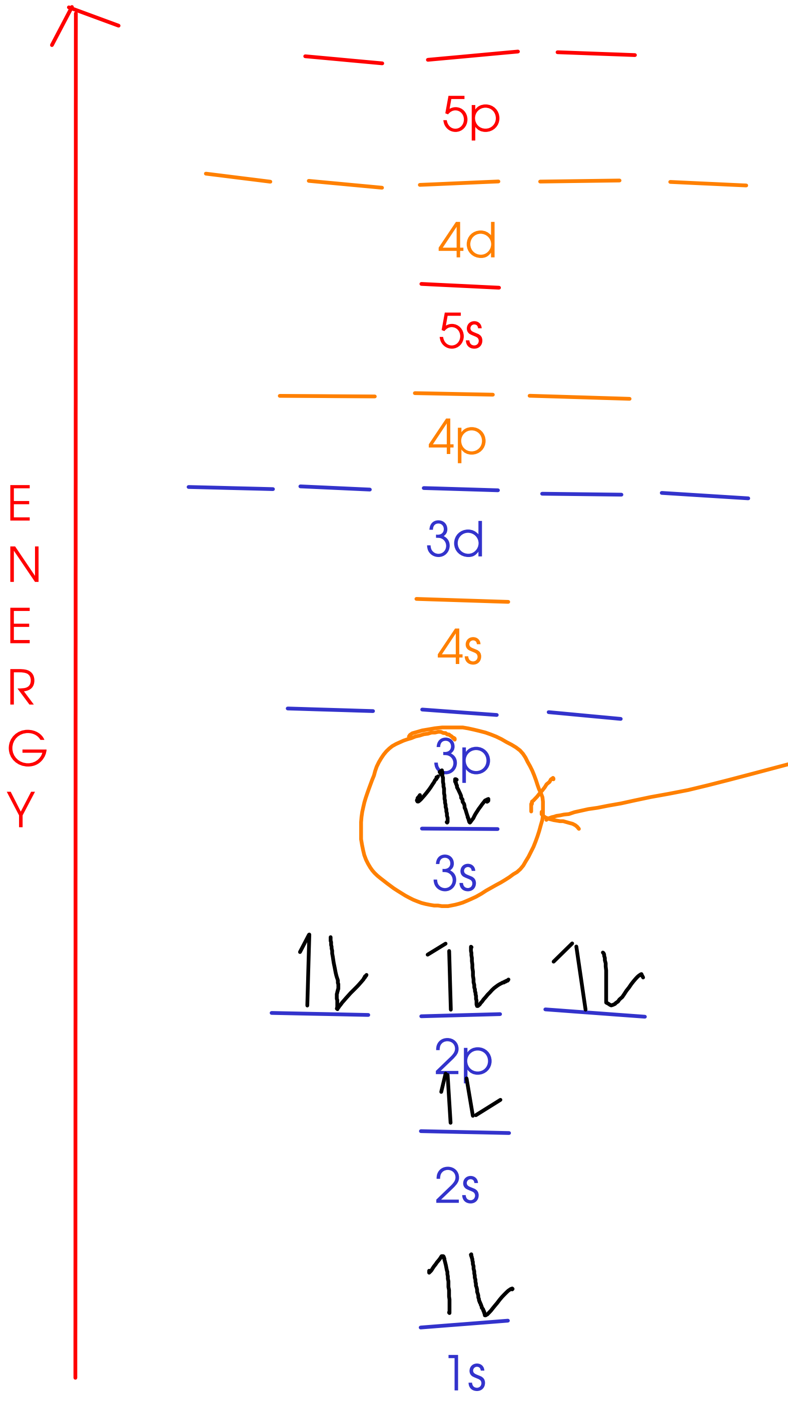
"1s" means first shell,
"s" subshell

Each blank represents an ORIBITAL which can hold up to TWO electrons

Let's look at some example atoms:

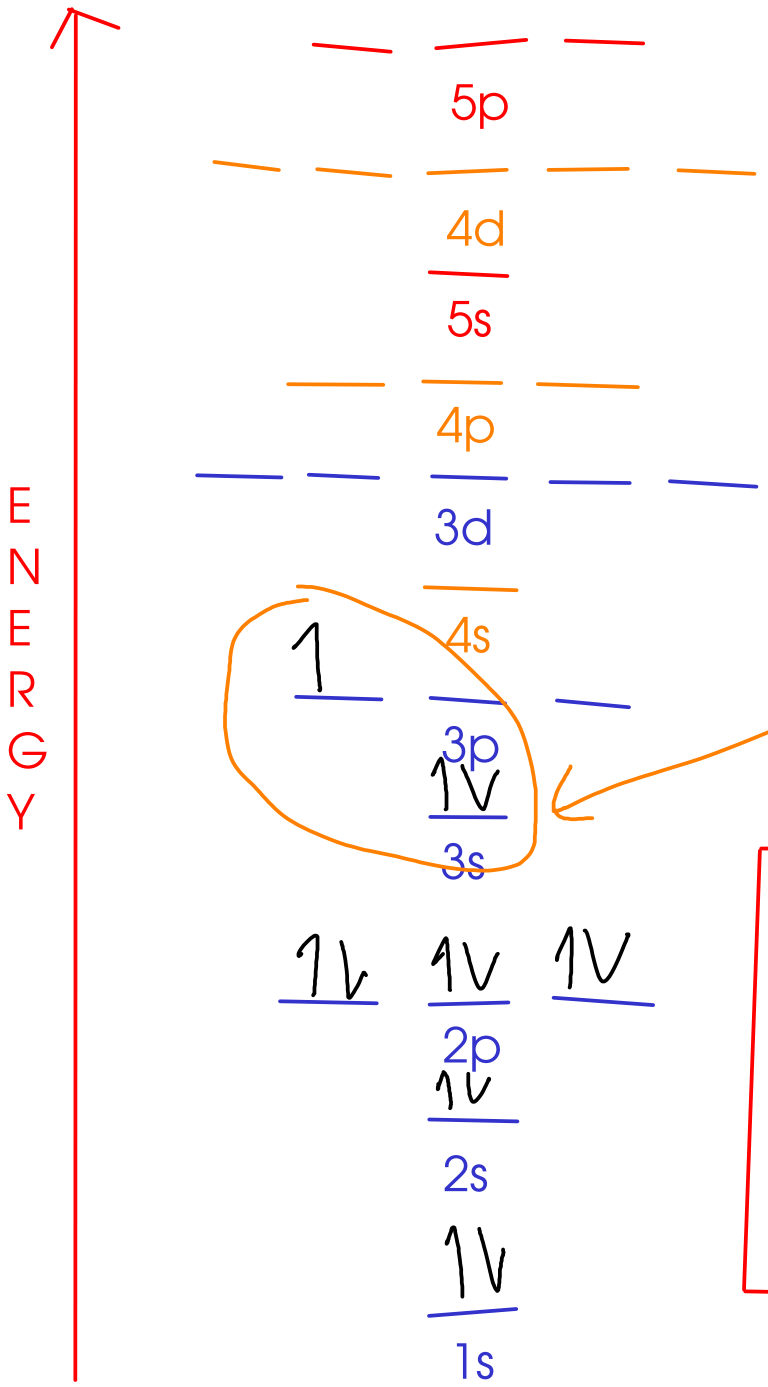
Magnesium: Z=12 , 12 electrons

↑ Z: atomic #



Outermost electrons of magnesium "valence electrons". These electrons are involved in chemical bonding!

Aluminum: Z = 13

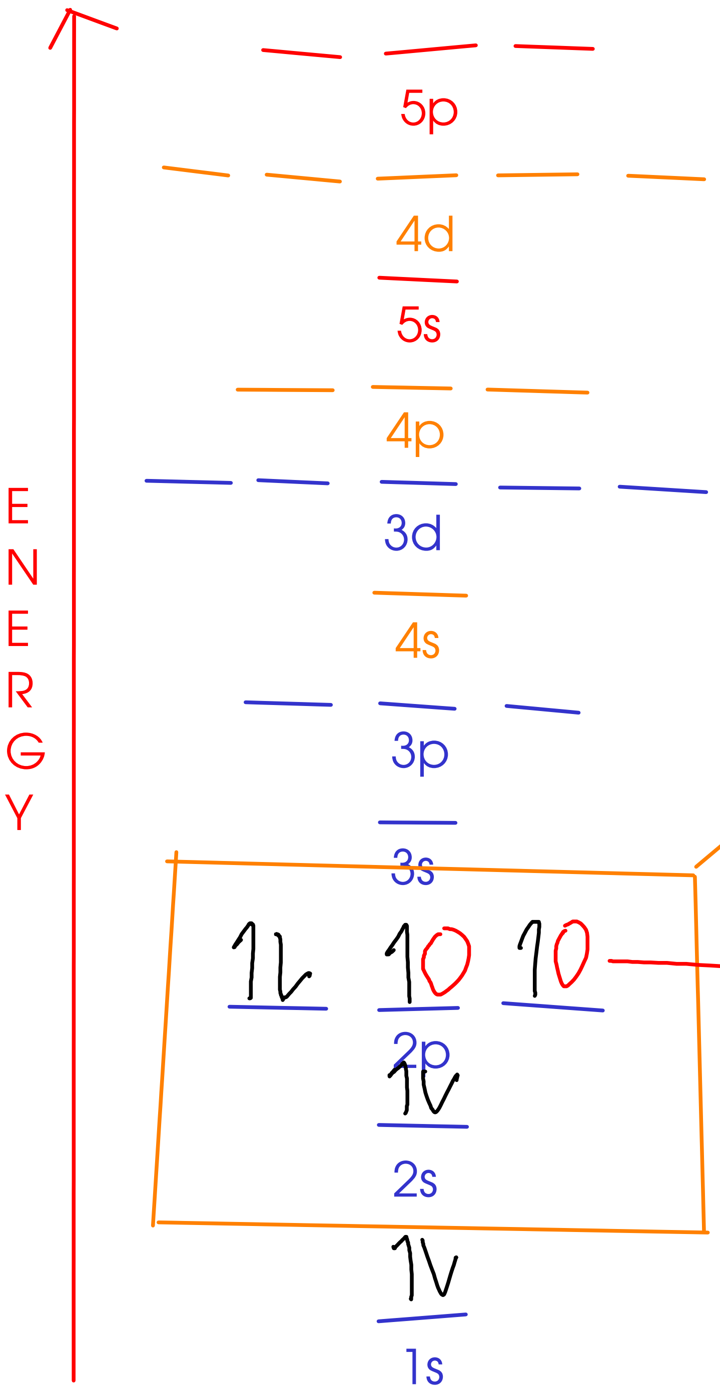


Aluminum has THREE valence electrons! (All electrons in the outer shell are valence electrons!)

Atoms tend to form ions or chemical bonds in order to end up with filled outer "s" and "p" subshells.

This is called the "octet" rule. (Not all chemical bonds follow this - it's a RULE OF THUMB, not a scientific law!)

Example: Oxygen, Z = 8



Valence electrons for oxygen. (6 electrons)

Oxygen needs two more electrons
to complete its outer "p" subshell!

In ionic compounds, oxygen has gained two electrons to become the oxide ion (2- charge). In molecular compounds, oxygen shares electrons with other atoms so that it has a share in eight electrons in its outer shell!

ELECTRON CONFIGURATION

- A shorthand way to write about electron arrangement around an atom.

$$O: \underbrace{1s}_{\text{Shell and subshell}}{}^{2}\,2s^{2}\,2p^{4}$$

Number of electrons in the subshell!

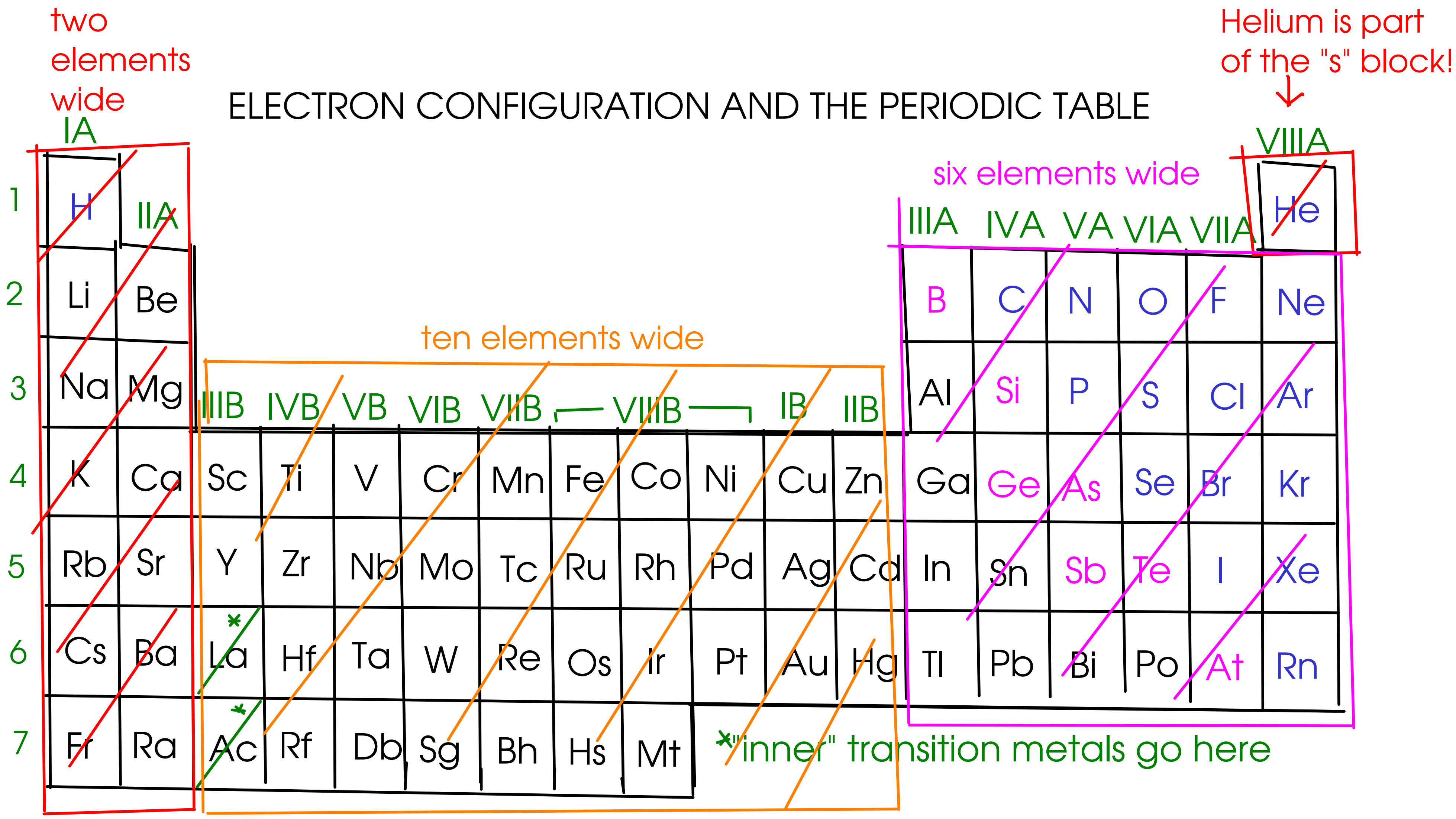
Shell
and
subshell

$$Mg: 1s^{2}2s^{2}2p^{6}\underline{3s^{2}}$$

$$Al: 1s^{2}2s^{2}2p^{6}\underline{3s^{2}3p^{1}}$$

Valence electrons are the ones in the outermost SHELL, not just the last subshell. Aluminum has THREE valence electrons.

ELECTRON CONFIGURATION AND THE PERIODIC TABLE



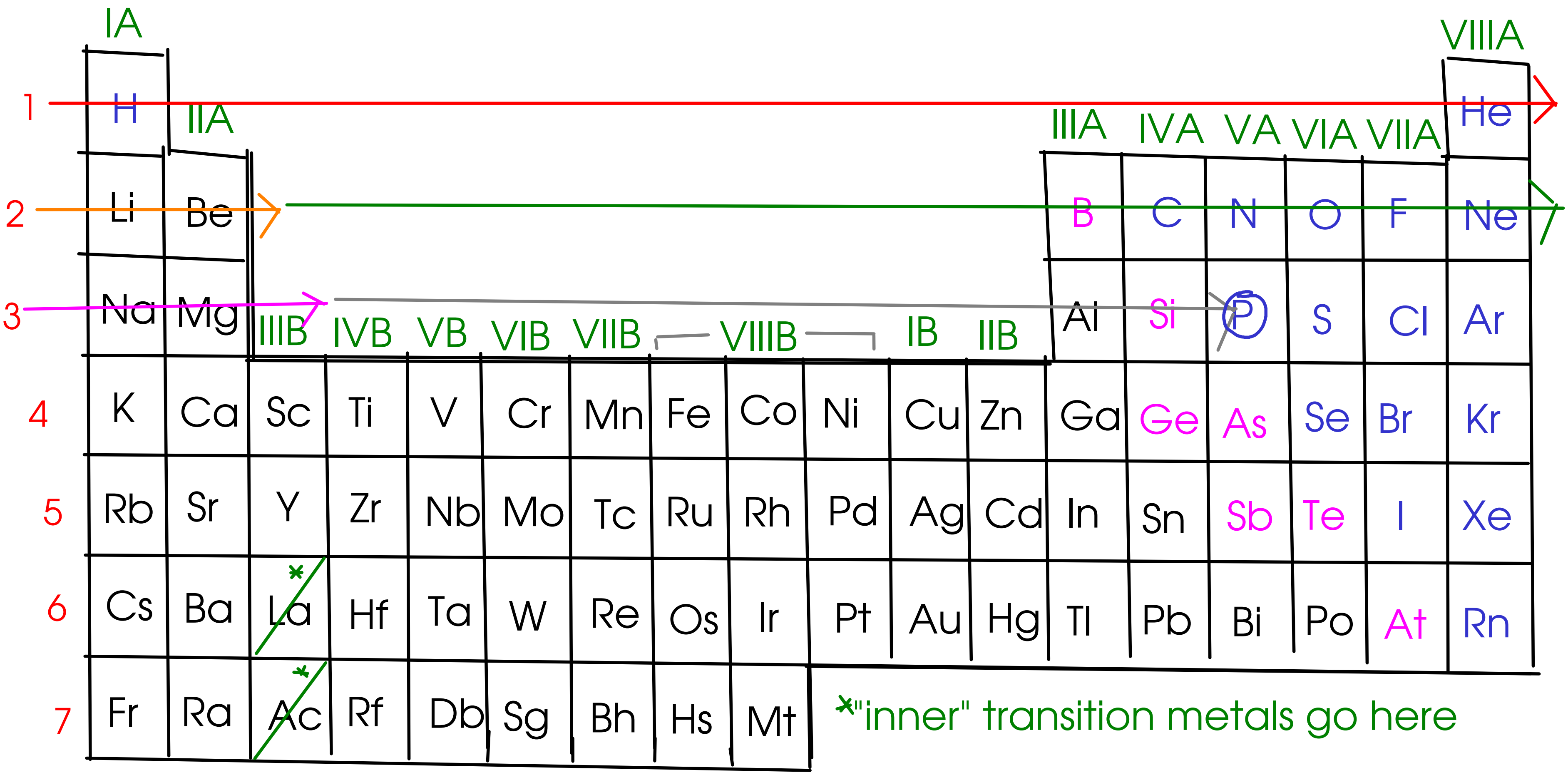
	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt									

"s" block: last electron in these atoms is in an "s" orbital!

"p" block: last electron in these atoms is in a "p" orbital!

"d" block: last electron is these atoms is in a "d" orbital

- To write an electron configuration using the periodic table, start at hydrogen, and count up the electrons until you reach your element!



	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H																	He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	*Ac	Rf	Db	Sg	Bh	Hs	Mt									

*"inner" transition metals go here

Example: Phosphorus (P): $1s^2 2s^2 2p^6 \underbrace{3s^2 3p^3}$

Phosphorus has FIVE valence electrons (all the electrons in the OUTER SHELL)

EXAMPLES:

F $1s^2\underline{2s^22p^5}$

Remember - valence electrons are ALL of the electrons in the outermost SHELL! (may have more than one SUBSHELL)!

S $1s^22s^22p^6\underline{3s^23p^4}$

TITANIUM is a transition metal that commonly forms either +2 or +4 cations. The 4s electrons are lost when the +2 ion forms, while the 4s AND 3d electrons are lost to form the +4!

Cl $1s^22s^22p^6\underline{3s^23p^5}$

$[Ne]3s^23p^5$

You can order the subshells in numeric order OR in filling order

Ti $1s^22s^22p^63s^23p^63d^2\underline{4s^2}$ or $1s^22s^22p^63s^23p^6\underline{4s^2}3d^2$

or $[Ar]3d^24s^2$

Se $1s^22s^22p^63s^23p^63d^{10}4s^24p^4$

or $[Ar]3d^{10}4s^24p^4$

Noble gas core notation. Use the previous noble gas on the table, then add the electrons that it doesn't have to the end.

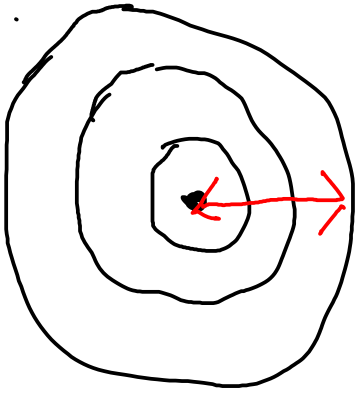
Kr $[Ar]3d^{10}\underline{4s^24p^6}$

You are responsible for writing electron configurations up to Z=18, Argon. These are here to illustrate other points!

PERIODIC TRENDS

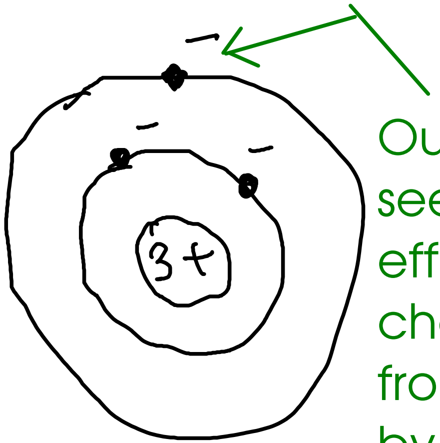
- Some properties of elements can be related to their positions on the periodic table.

ATOMIC RADIUS



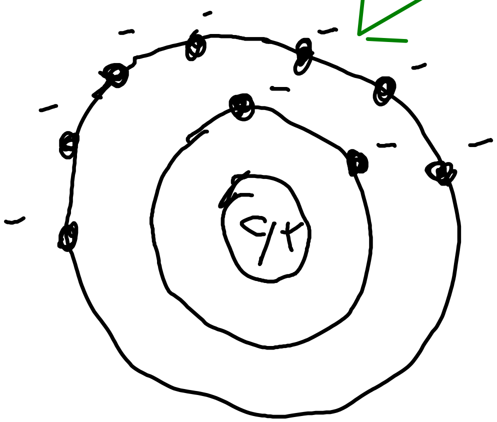
- The distance between the nucleus of the atoms and the outermost shell of the electron cloud.
- Relates to the size of the atom.
- As you go DOWN A GROUP (↓), the atomic radius INCREASES.
  - Why? As you go down a period, you are ADDING SHELLS!
- As you go ACROSS A PERIOD (⟶), the atomic radius DECREASES

Why? Let's look at some sample atoms.



lithium

Outer electron sees an effective +1 charge (shielded from +3 nucleus by 2 electrons)



fluorine

Outer electrons see an effective +7 charge (shielded from +9 nucleus by 2 electrons)

... so fluorine's outer shell is pulled closer to the nucleus than lithium's!

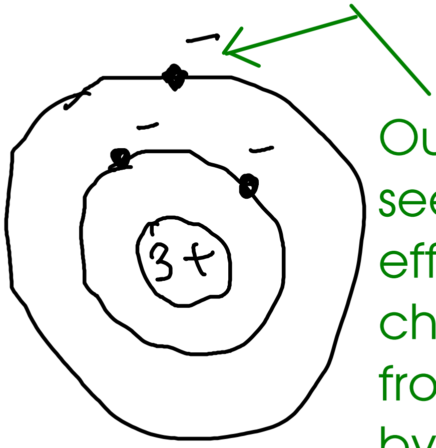
IONIZATION ENERGY (or FIRST IONIZATION ENERGY)

- The amount of energy required to remove a single electron from the outer shell of an atom.
- Relates to reactivity for metals. The easier it is to remove an electron, the more reactive the metal.
- As you go DOWN A GROUP (↓), the ionization energy DECREASES.

  - Why? As you go down a period, you are ADDING SHELLS. Since the outer electrons are farther friom the nucleus and charge attraction lessens with distance, this makes electrons easier to remove as the atoms get bigger!

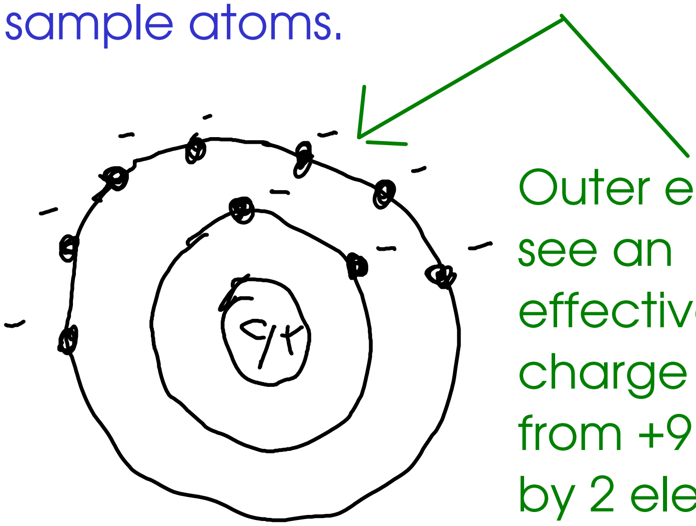
- As you go ACROSS A PERIOD (⟶), the ionization energy INCREASES.

  - Why? Let's look at some sample atoms.



Outer electron sees an effective +1 charge (shielded from +3 nucleus by 2 electrons)

lithium

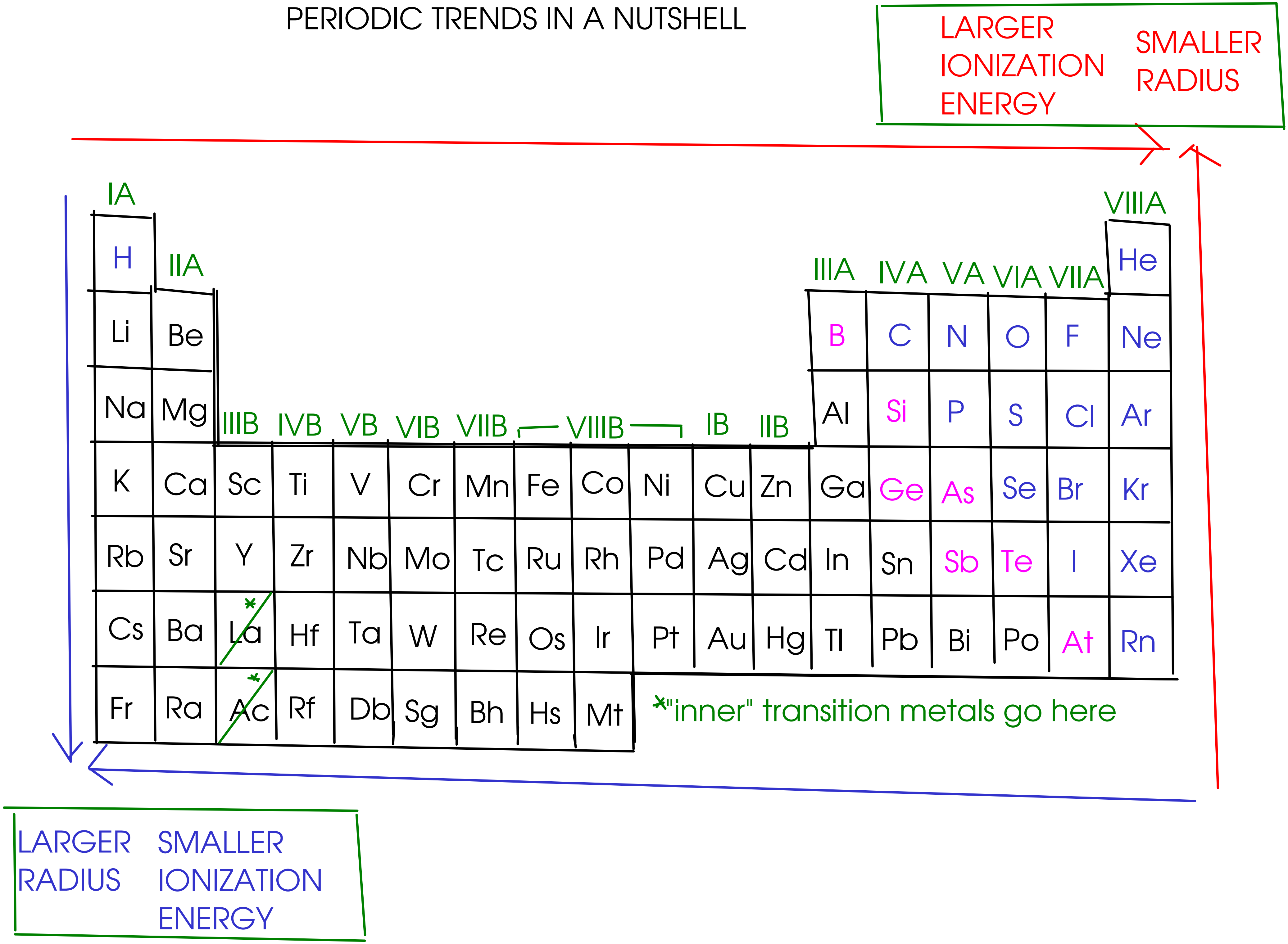


Outer electrons see an effective +7 charge (shielded from +9 nucleus by 2 electrons)

fluorine

... since fluorine's outer electrons are held on by a larger effective charge, they are more difficult to remove than lithium's.

PERIODIC TRENDS IN A NUTSHELL



LARGER IONIZATION ENERGY

SMALLER RADIUS

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	*Ac	Rf	Db	Sg	Bh	Hs	Mt									

*"inner" transition metals go here

LARGER RADIUS

SMALLER IONIZATION ENERGY