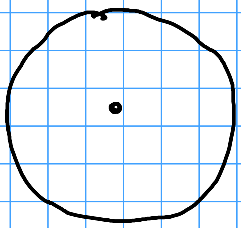
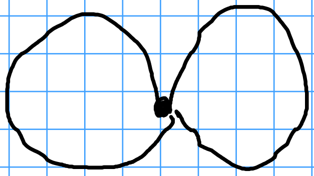
SUBSHELLS: Within a SHELL, electrons may move in different ways around the nucleus! These different "paths" are called SUBSHELLS

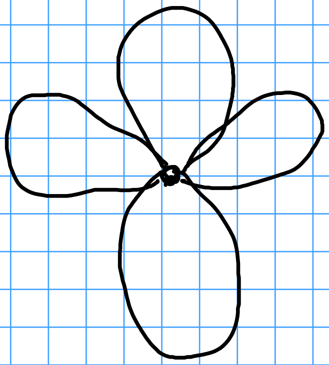
- SHAPES of regions of space that electrons are able to exist in.



"s" subshell
(a spherical region)



"p" subshell
(a dumbbell shaped region)



"d" subshell

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

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

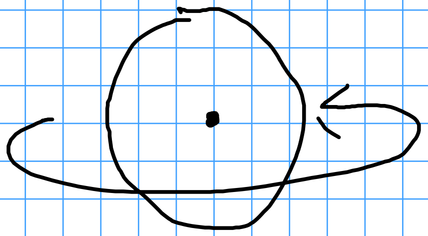
- Each orbital may, at most, contain TWO ELECTRONS

ARRANGEMENT OF SHELLS, SUBSHELLS, AND ORBITALS

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

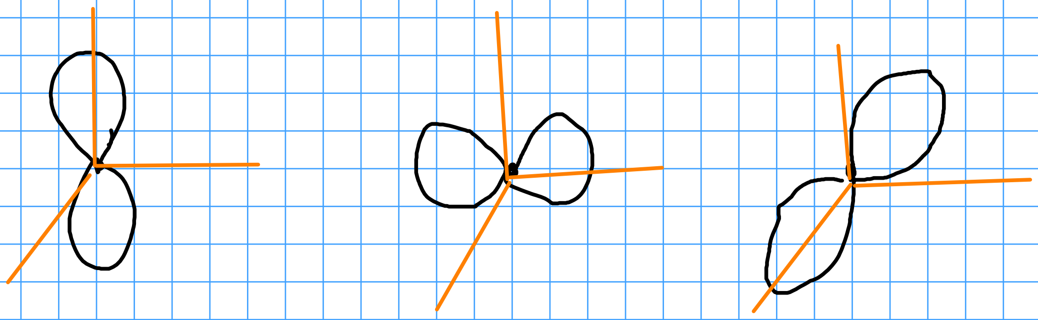
1st shell: ONE possible subshell (s)
2nd shell: TWO possible subshells (s, p)
3rd shell: THREE possible subshells (s, p, d)
4th shell: FOUR possible subshells (s, p, d, f)
... and so on

- 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

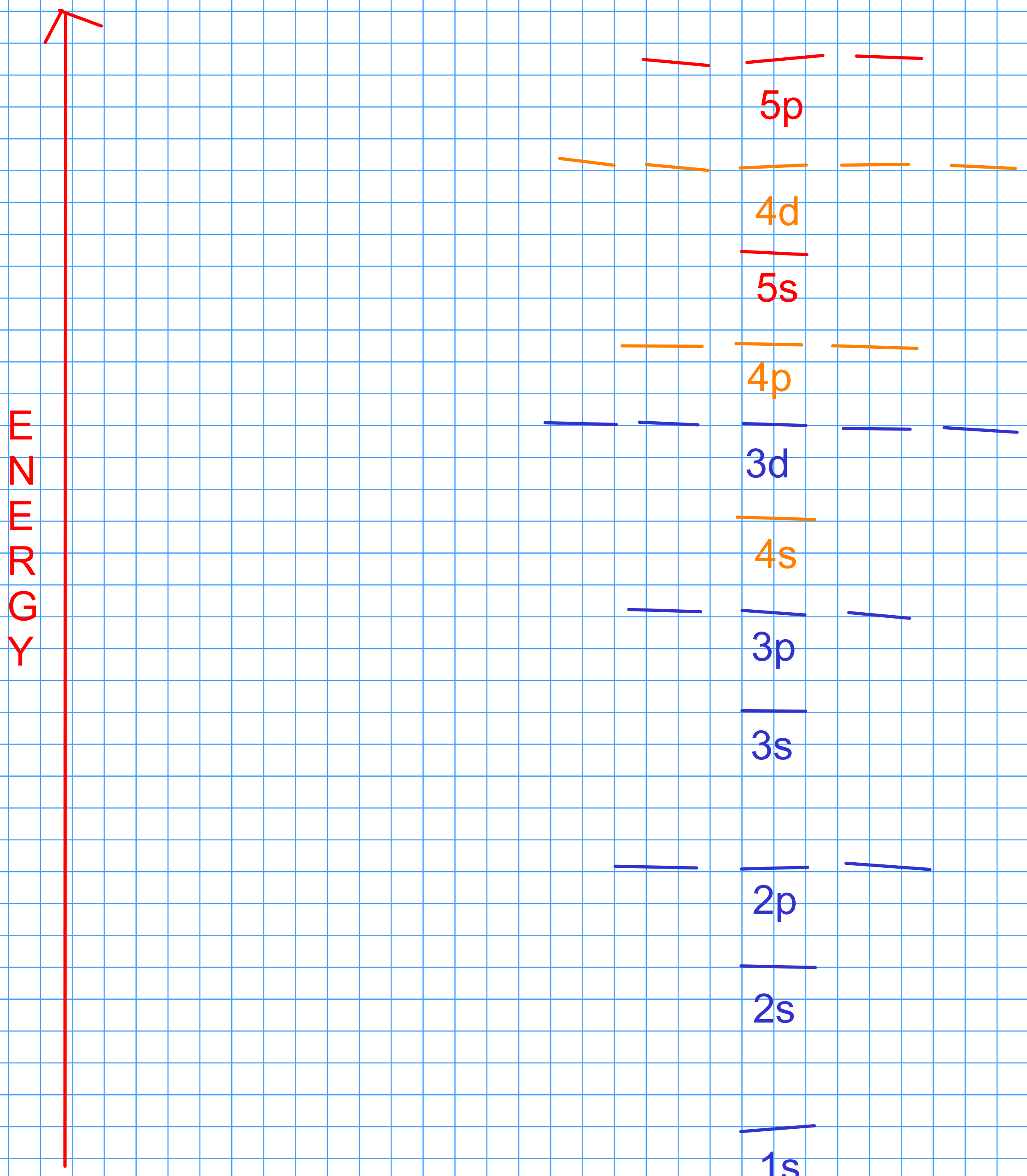
- There are five possible orbitals in a "d" subshell, and 7 possible orbitals in an "f" subshell!

Maximum 10 electrons
in 5 orbitals

Maximum 14 electrons
in 7 orbitals

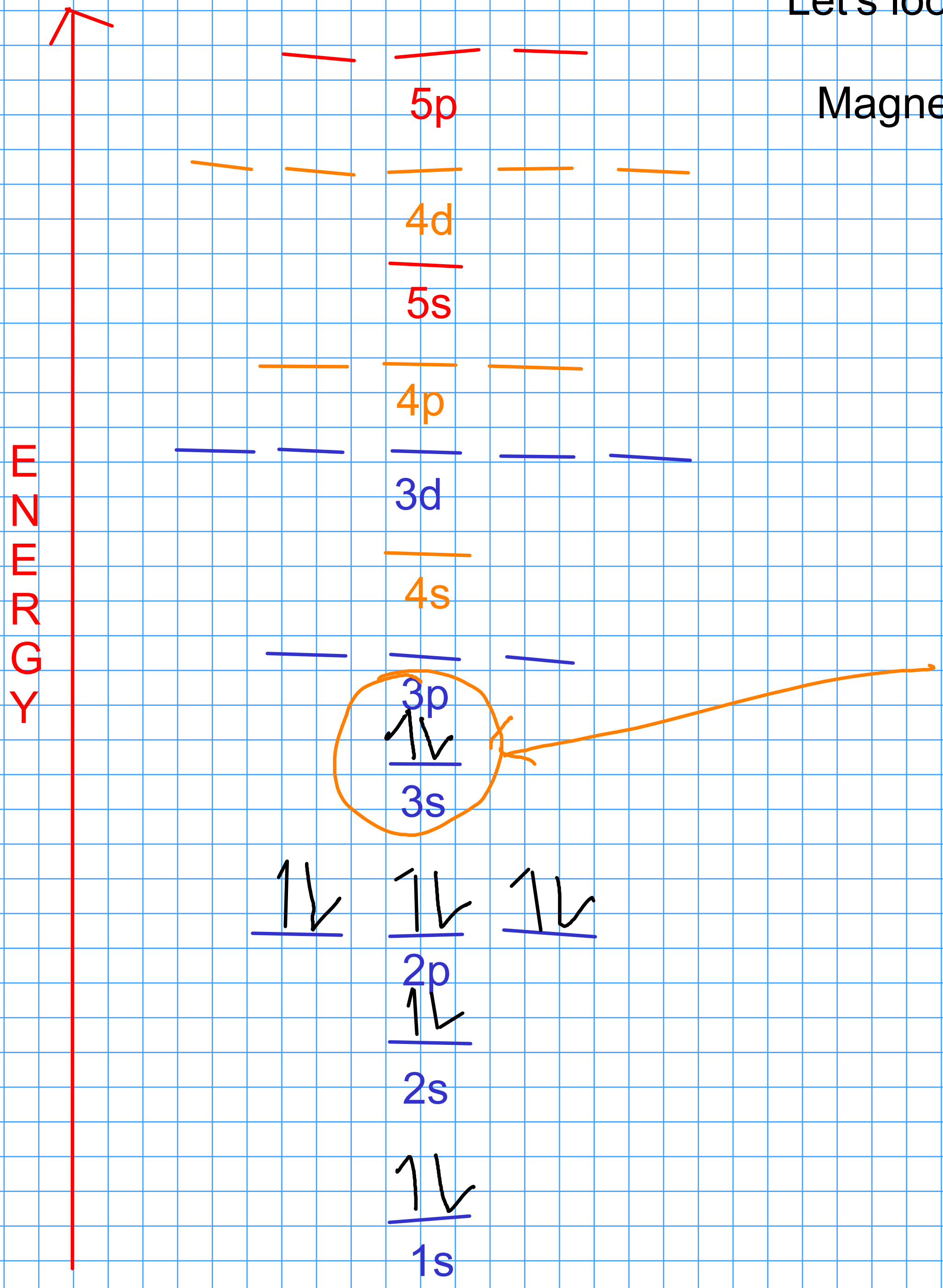
ENERGY DIAGRAM

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



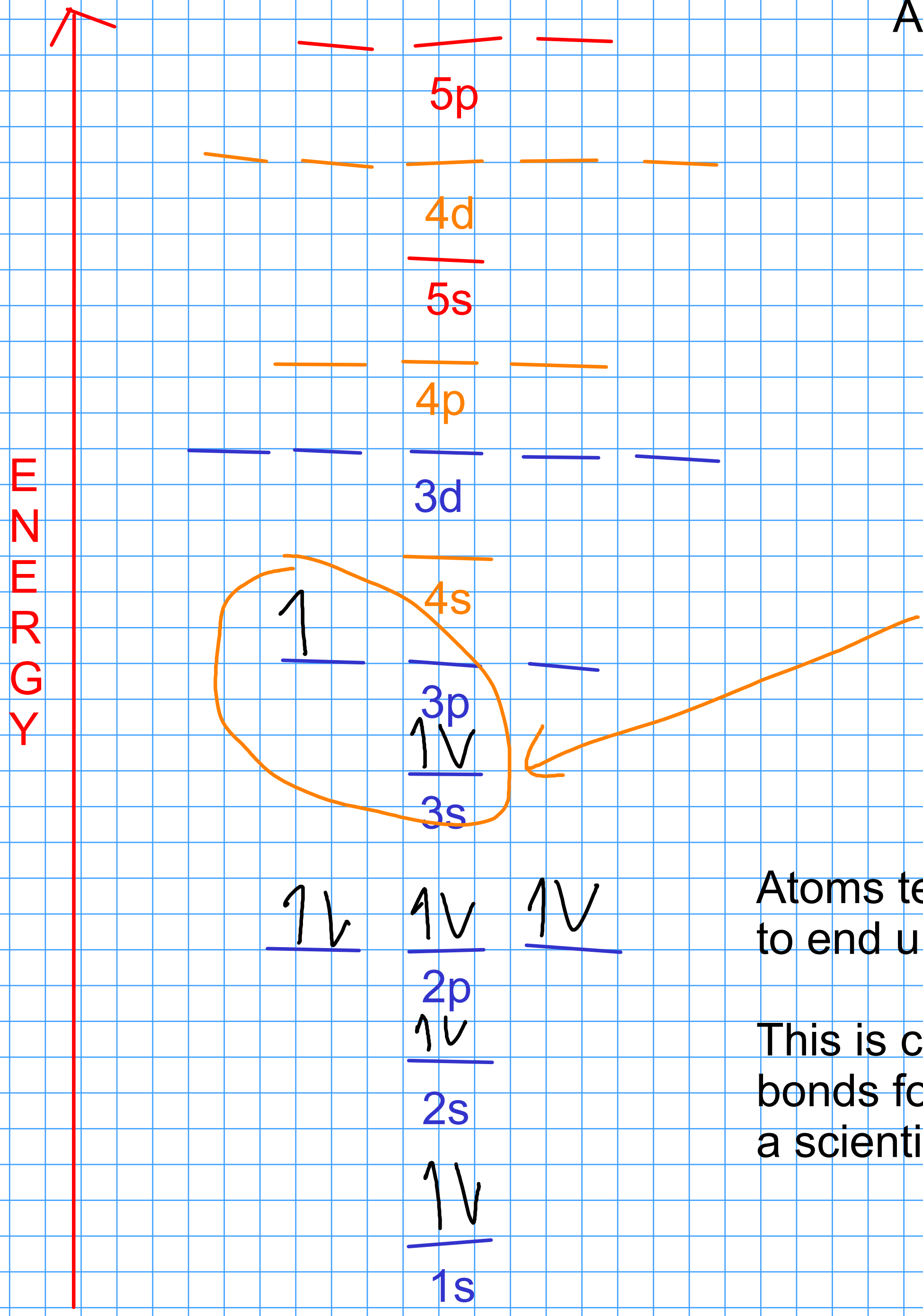
Let's look at some example atoms:

Magnesium: Z=12 , 12 electrons



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

Aluminum: Z = 13

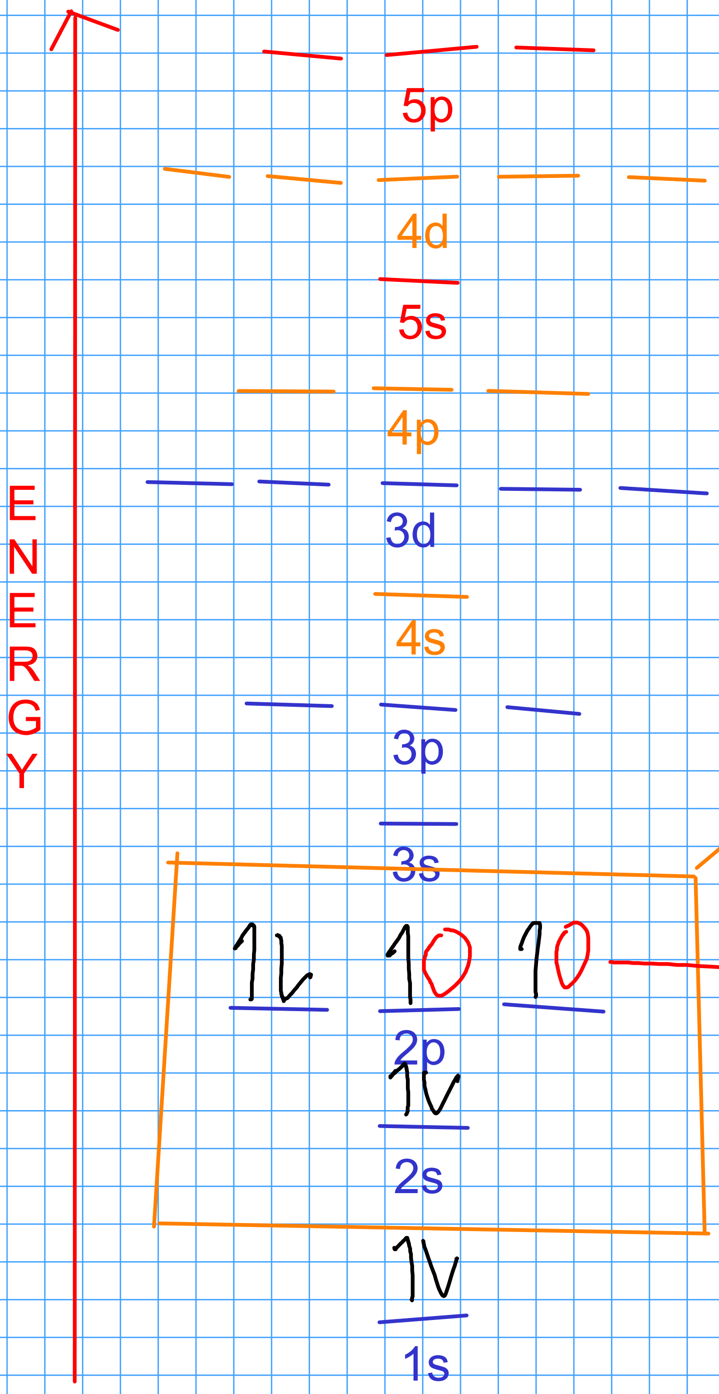


Aluminum has THREE valence electrons!
(All electrons in the outer shell are valence
electrons!)

Atoms tend to form ions or chemical bonds in order
to end up with filled "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.

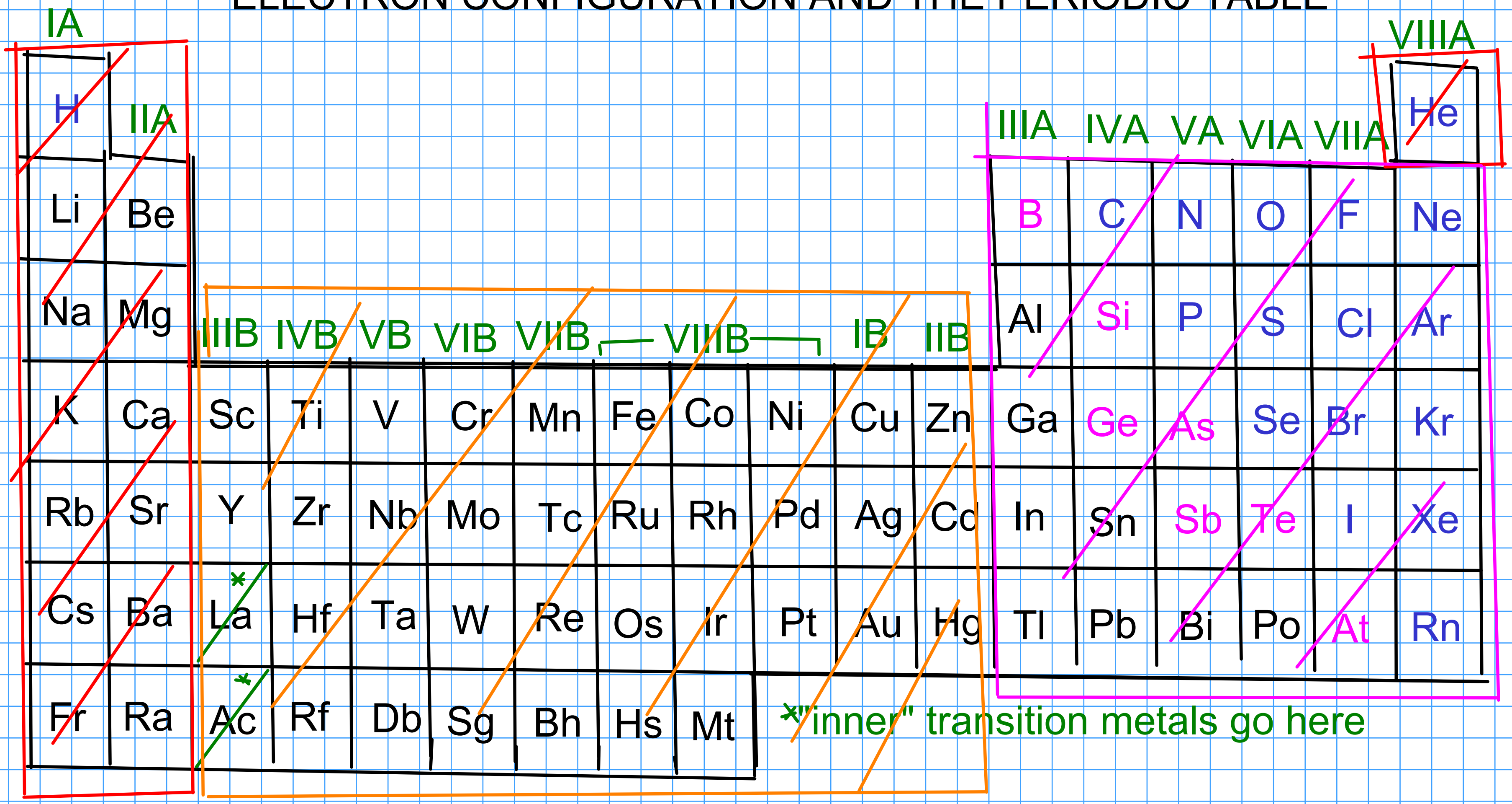
$$O: \underbrace{1s}_{\text{Shell and subshell}}{}^{2}\,2s^{2}\,2p^{\boxed{4}}$$

Number of electrons in the subshell!

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

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

ELECTRON CONFIGURATION AND THE PERIODIC TABLE



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									

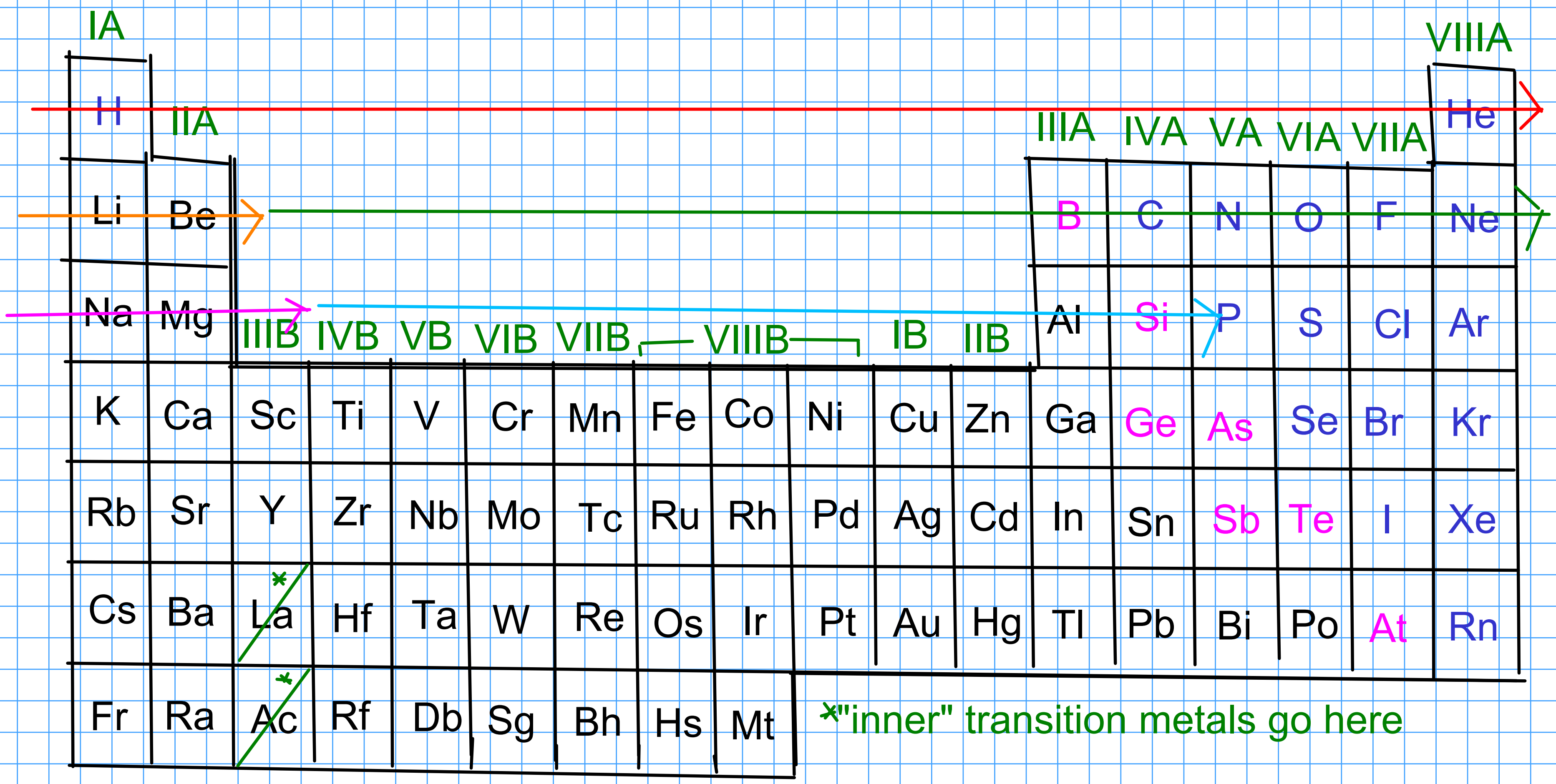
*"inner" transition metals go here

"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
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									

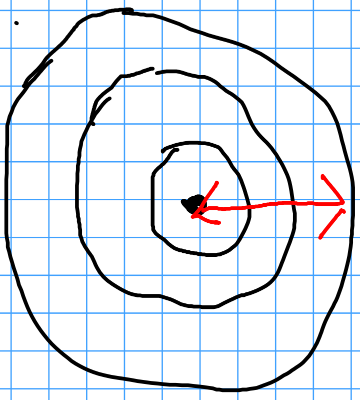
*"inner" transition metals go here

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

Phosphorus has five valence electrons!

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.

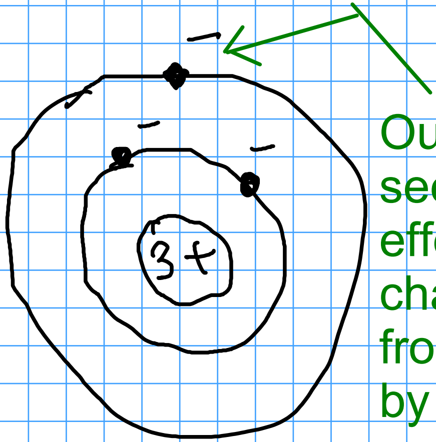
- Relates to the size of the atom.

- As you go DOWN A GROUP (↓), the atomic radius INCREASES.

  - Why? As you go down a period, you are ADDING SHELLS!

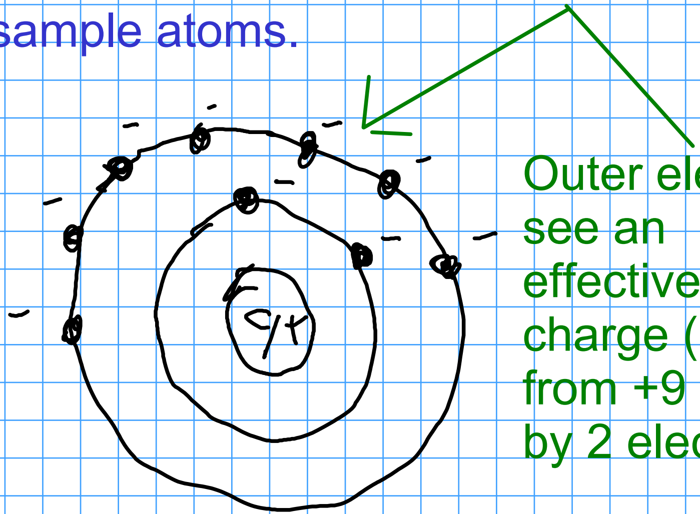
- As you go ACROSS A PERIOD (⟶), the atomic radius DECREASES

  Why? Let's look at some sample atoms.



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

lithium



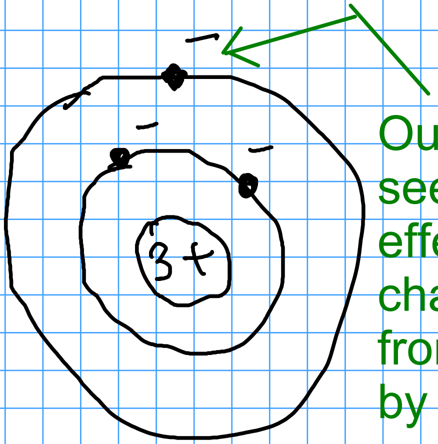
Outer electrons see an effective -7 charge (shielded from +9 nucleus by 2 electrons)

fluorine

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

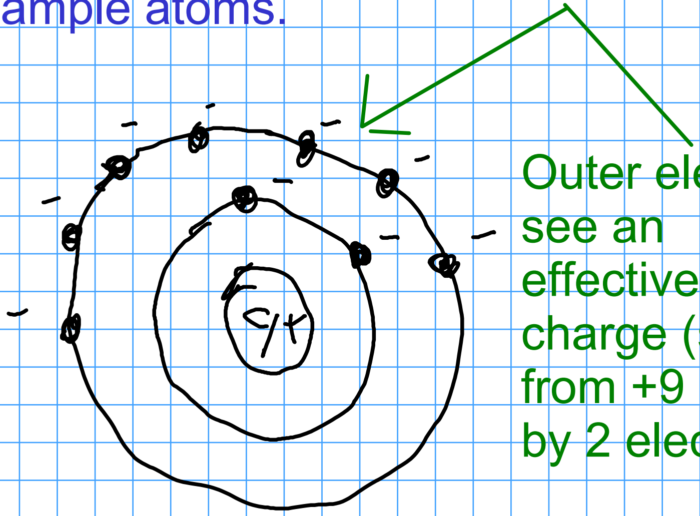
IONIZATION ENERGY

- 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 ebergy 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)

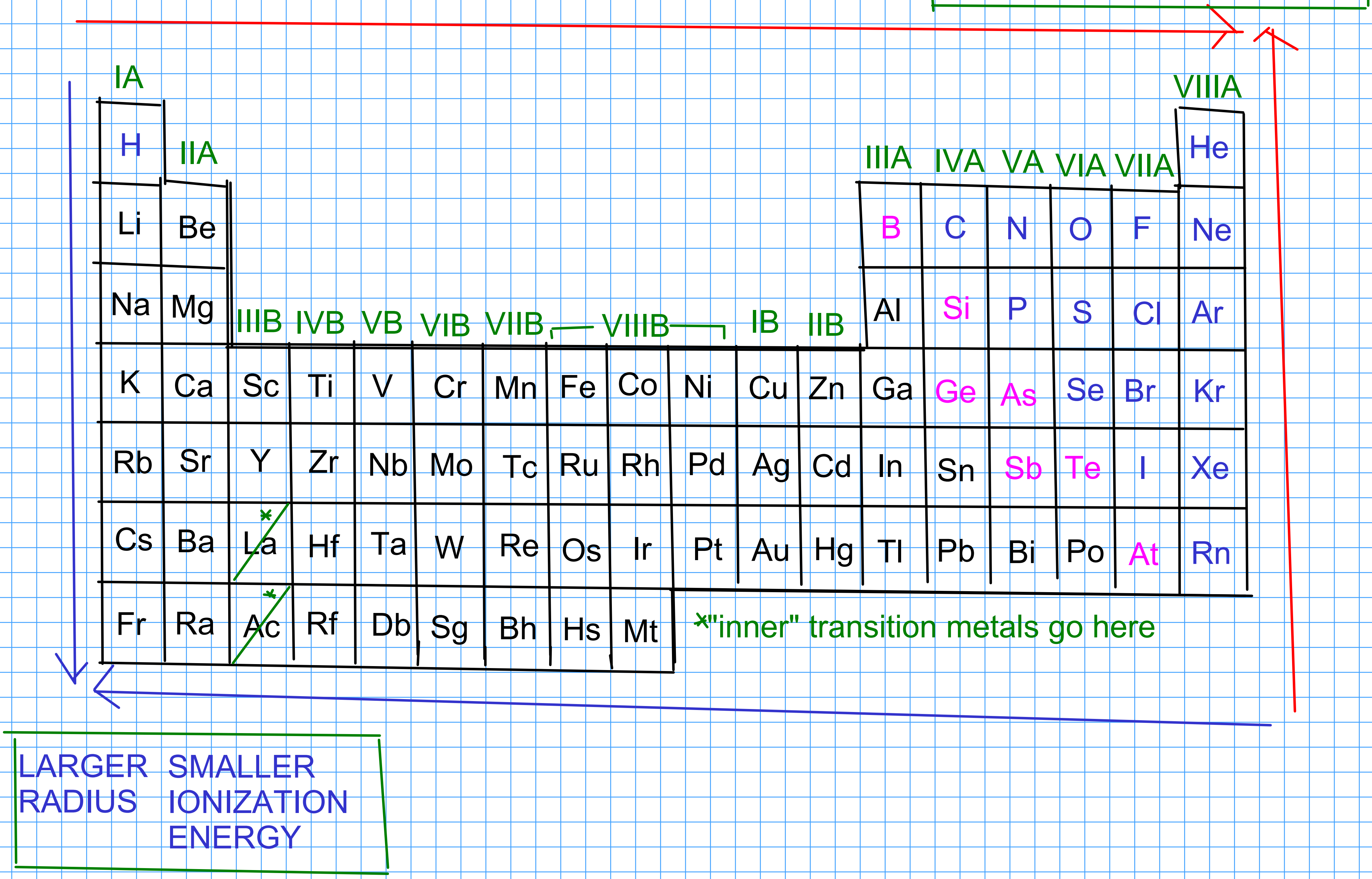
fluorine

... 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
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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