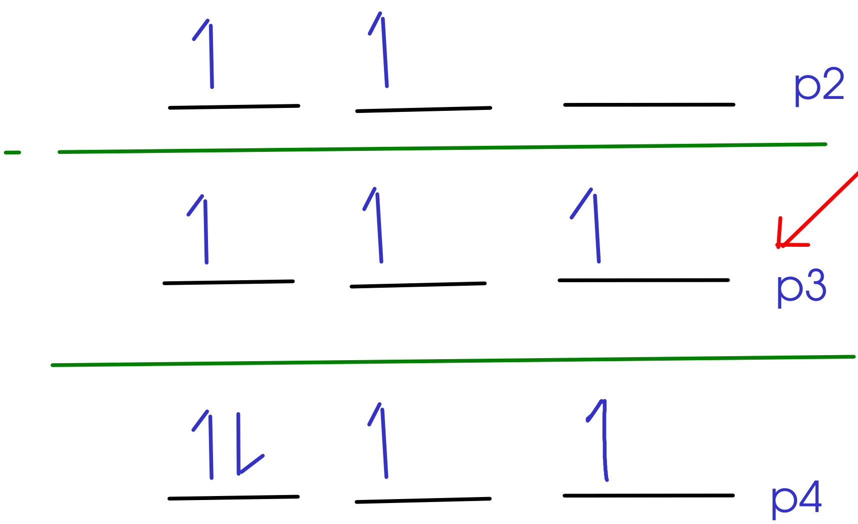
Hund's Rule

- When you have two or more orbitals with equivalent energy, electrons will go into each equivalent orbital BEFORE pairing. Pairing costs a bit of energy - less than going to a higher-energy orbital, but more than going to another equivalent orbital.



Electron configurations with filled subshells OR HALF-FILLED SUBSHELLS are more stable than other configurations.
(can explain some transition metal chemistry)

Electrons begin to pair only AFTER all equivalent "p" orbitals are full.

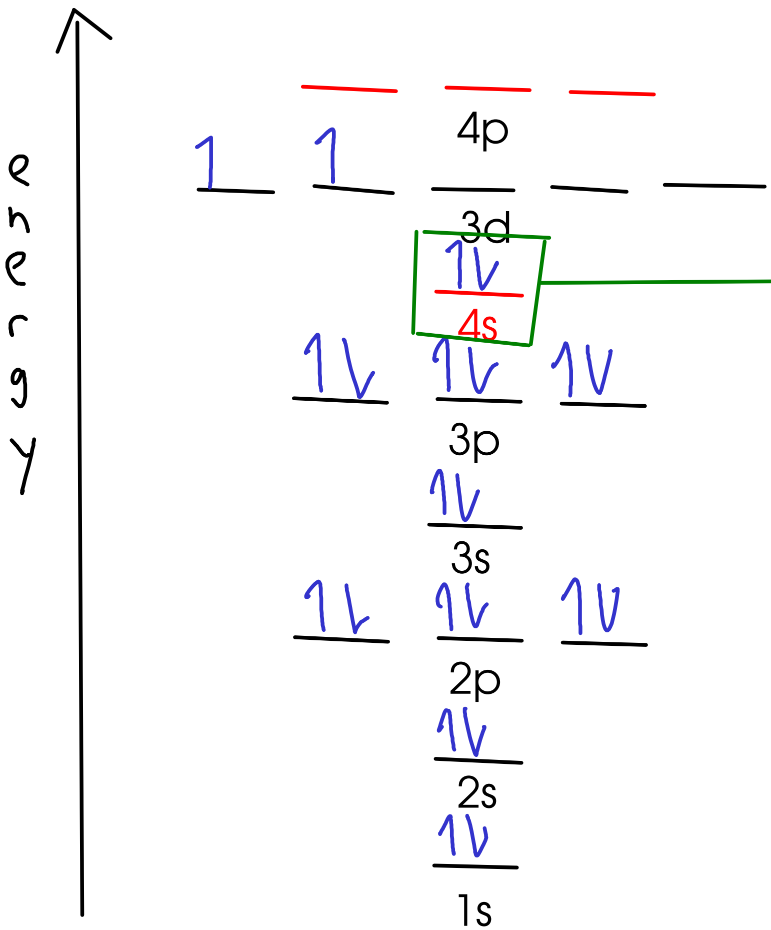
Experimental evidence for Hund's rule:

"Paramagnetism" - attraction of an atom to a magnetic field

* Spinning electrons are magnetic, but OPPOSITE spins cancel each other out.

* Atoms with unpaired electrons are paramagnetic, while atoms containing only paired electrons are not.

A little bit about transition metals...



Titanium (Ti, Z = 22)

Titanium usually forms one of two ions: +2 and +4

- if Ti loses only the valence electrons, forms +2. If it also loses the 3d electrons, forms +4.

valence electrons

- Most transition metals have TWO valence electrons (in an "s" subshell), and the other ions they form come from electron loss in "d" subshells.

ELECTRON CONFIGURATION (SHORT FORM)

- We can represent the electron configuration without drawing a diagram or writing down pages of quantum numbers every time. We write the "electron configuration".

# of electrons in the subshell

Ti: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 \underbrace{4s^2}_{\text{valence electrons}}$

n ℓ

Valence electrons have the largest value for "n"!

Ti: $\underbrace{[Ar]}_{\text{noble gas core}} 3d^2 \underbrace{4s^2}_{\text{valence electrons}}$

"noble gas core". We're saying that titanium has the same electron configuration as argon does, with the addition of the electrons that follow. This is a useful shorthand, since the "core" electrons generally don't get involved in bonding.

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 in 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!

"d" block: The d block is shifted DOWN.!

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	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 4s	Ca	Sc 3d	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga 4p	Ge	As	Se	Br	Kr
5	Rb	Sr	Y 4d	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	* ~~La~~ 5d	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	* ~~Ac~~ 6d	Rf	Db	Sg	Bh	Hs	Mt									

*"inner" transition metals go here

Example: Phosphorus (P): $1s^2 2s^2 2p^6 3s^2 3p^3$

Noble gas core notation for P: $[Ne] 3s^2 3p^3$

EXAMPLES:

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

Remember - valence electrons are ALL of the electrons in the outermost SHELL (n)! More that one subshell (l) may be included in the valence electrons

S $1s^2 2s^2 2p^6 \underline{3s^2 3p^4}$

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 $1s^2 2s^2 2p^6 \underline{3s^2 3p^5}$

$[Ne]3s^2 3p^5$

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

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

or $[Ar]3d^2 4s^2$

Se $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$

or $[Ar]3d^{10} 4s^2 4p^4$

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 $[Ar]3d^{10} \underline{4s^2 4p^6}$

~~[Kr]~~

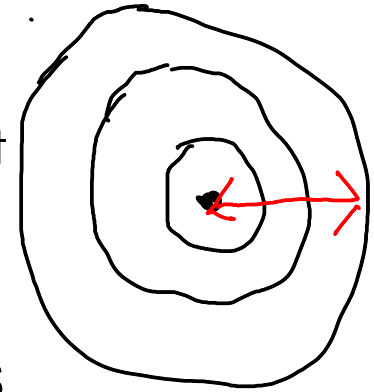
Sample f-block element

Ce: $[Xe]6s^2 5d^1 4f^1$

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.

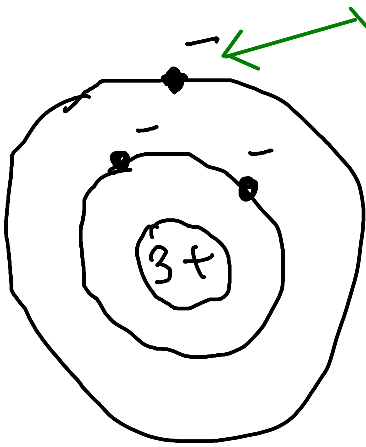
- Relates to the size of the atom.

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

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

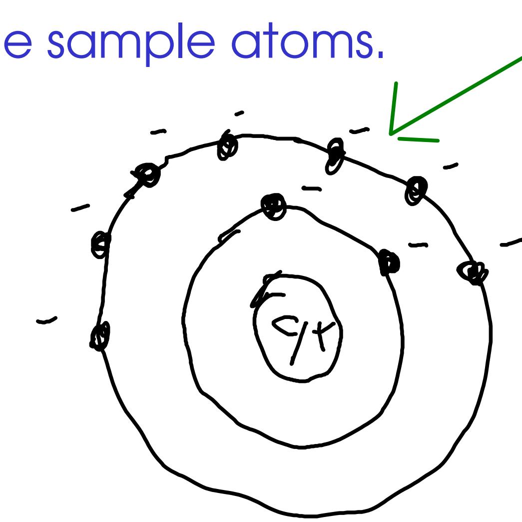
- As you go ACROSS A PERIOD (⟶), the atomic radius DECREASES

  Why? Let's look at some sample atoms.



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

lithium $1s^2 2s^1$



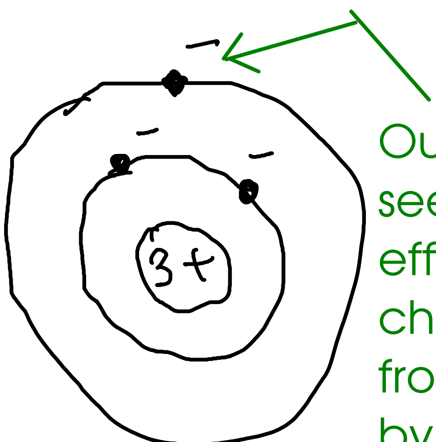
Outer electrons see an effective +7 charge (shielded from +9 nucleus by 2 electrons)

fluorine $1s^2 2s^2 2p^5$

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

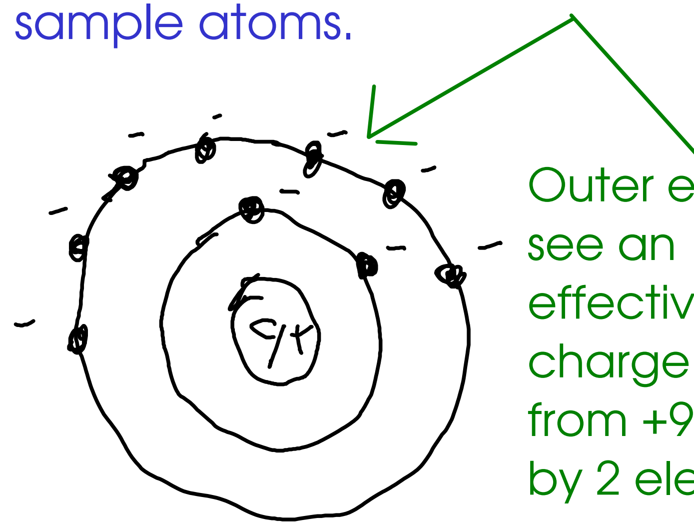
(FIRST) IONIZATION ENERGY

- 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 from 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.

THE FIRST TWO 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

ELECTRON AFFINITY

- the electron affinity is the ENERGY CHANGE on adding a single electron to an atom.
  - Atoms with a positive electron affinity cannot form anions.
  - The more negative the electron affinity, the more stable the anion formed!

- General trend: As you move to the right on the periodic table, the electron affinity becomes more negative.

EXCEPTIONS

- Group IIA does not form anions (positive electron affinity)!

ns^2 valence electrons for Group IIA!

n period number

- To add an electron, the atom must put it into a higher-energy (p) subshell.

- Group VA: can form anions, but has a more POSITIVE electron affinity than IVA

ns^2np^3 valence electrons for Group VA!

np^3 Half-full "p" subshell! To add an electron, must start pairing!

- Group VIIIA (noble gases) does not form anions

ns^2np^6 full "s" and "p" subshells!

"MAIN" or "REPRESENTATIVE" GROUPS OF THE PERIODIC TABLE

	IA	IIA	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	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra						

Read about these in Section 8.7 of the Ebbing textbook!

Alkaline earth metals

Alkali metals

Chalcogens

Halogens

Noble/Inert gases

The representative (main) groups

GROUP IA - the alkali metals

valence electrons:

ns^1

- React with water to form HYDROXIDES

$$2M + 2H_2O \rightarrow \underline{2MOH} + H_2$$

alkali metals form BASES when put into water!

- Alkali metal OXIDES also form bases when put into water. (This is related to METALLIC character. The more metallic something is, the more basic its oxide. Nonmetals have ACIDIC oxides!) M_2O

- Physical properties: All of these elements are soft metals with relatively low melting points.

GROUP IIA - the alkaline earth metals

valence electrons:

ns^2

- May react with water in a reaction similar to the alkali metals, producing hydroxides and hydrogen gas. For some of the alkaline earth metals, this reaction takes place at a significant rate only at high temperatures..

- Form basic oxides, formula: MO

- These elements are soft and low-melting ... but harder and higher melting than alkali metals.

- The name "alkaline earth" comes from the observation that the "earths" (oxides) of these metals are basic.