notes

NEED Whiteboards & Element Signs for forming atoms

See teacher notes on lesson

Edit this to avoid repetition after we have learned it

Periodic Trends

Elemental Properties and Patterns

The Periodic Law

- Dimitri Mendeleev was the first scientist to publish an organized periodic table of the known elements.

The Periodic Law

- Mendeleev even went out on a limb and predicted the properties of 2 at the time undiscovered elements.
- He was very accurate in his predictions, which led the world to accept his ideas about periodicity and a logical periodic table.

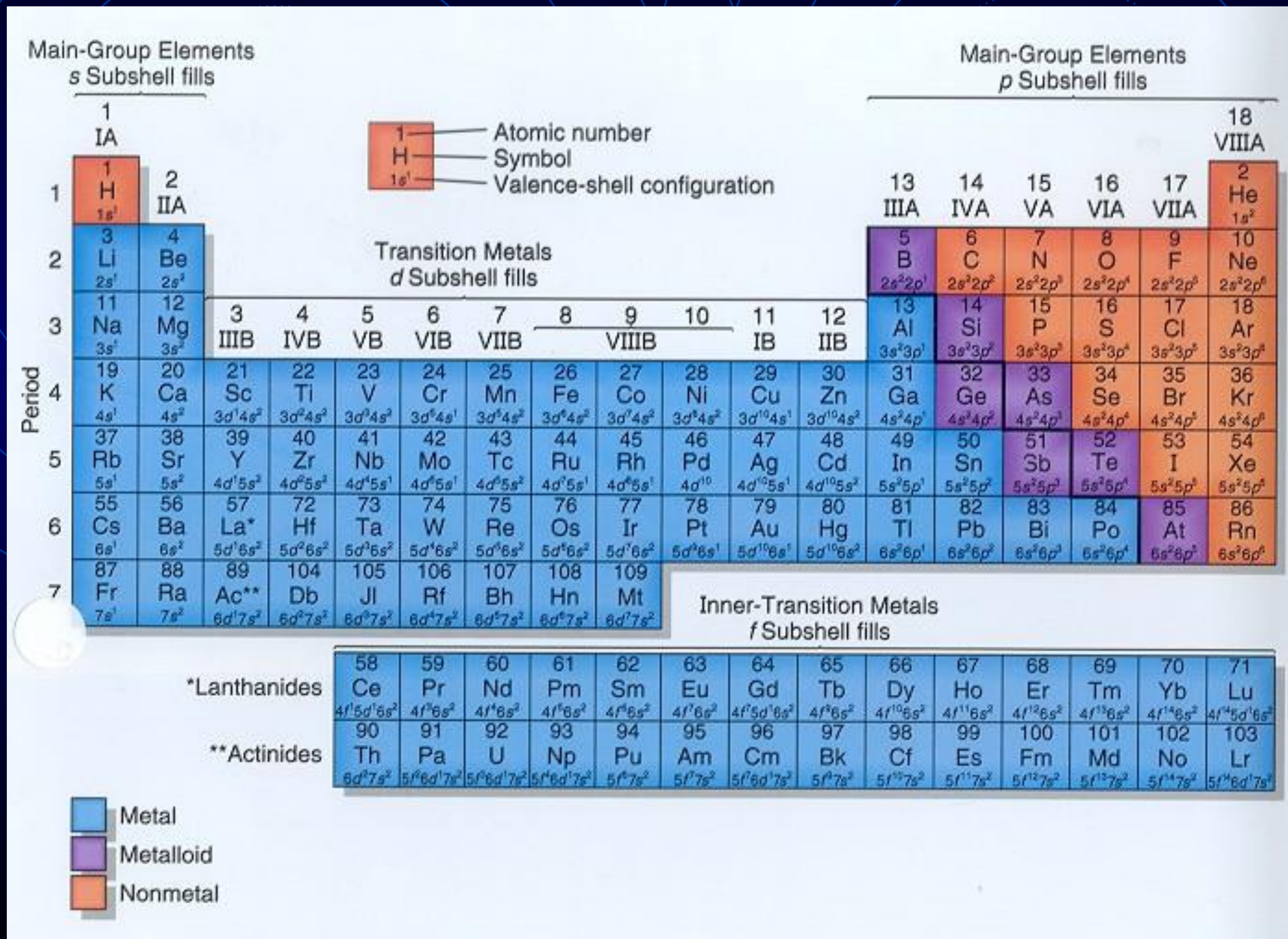
The Periodic Law

- Mendeleev understood the ‘Periodic Law’ which states:
- When arranged by increasing atomic number, the chemical elements display a regular and repeating pattern of chemical and physical properties.

The Periodic Law

- Atoms with similar properties appear in groups or families (vertical columns) on the periodic table.
- They are similar because they all have the same number of valence (outer shell) electrons, which governs their chemical behavior.

Metals, Nonmetals, Metalloids



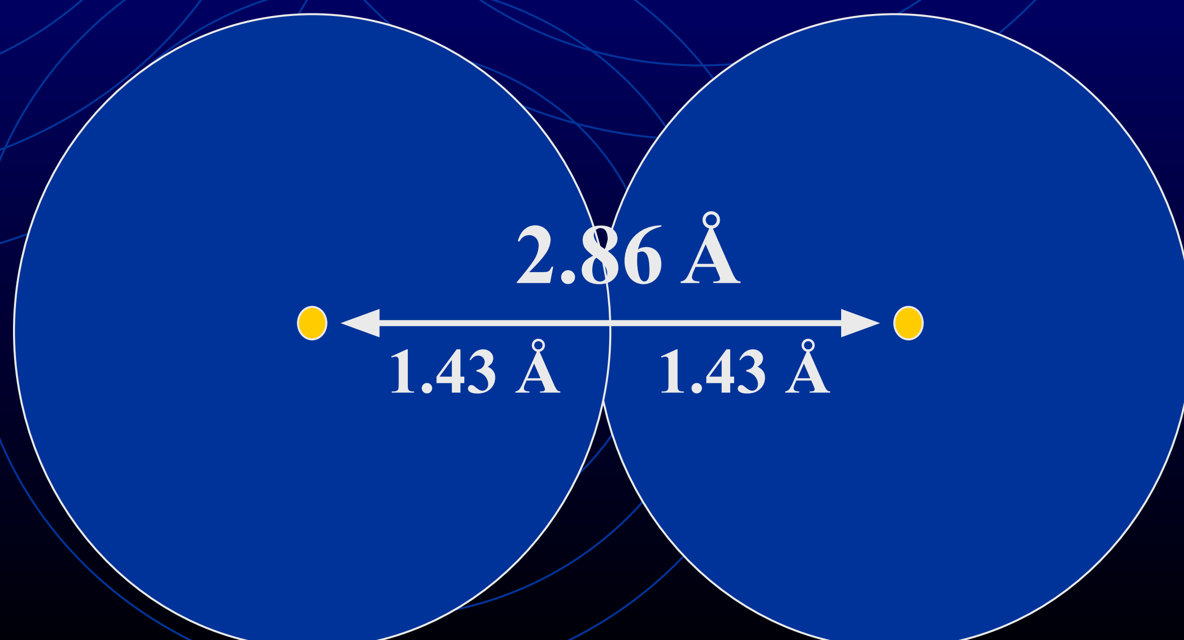
Periodic Trends

- There are several predictable trends in properties that you should know.
- The first and most important is atomic radius.
- Radius is the distance from the center of the nucleus to the "edge" of the electron cloud.

Atomic Radius
(for interest only slide)

- Since a cloud's edge is difficult to define, scientists use covalent radius, or half the distance between the nuclei of 2 bonded atoms.

Atomic radii are usually measured in picometers (pm) or angstroms (Å). An angstrom is 1 x 10^{-10} m.



In your partners

- Partner A → Draw B-R of Li
- Partner B → Draw B-R of Na
- Discuss → which is larger and why?
- Stand up if you are the largest atom
- Explain
- BUT Na is even larger than is anticipated from the added energy level → WHY?

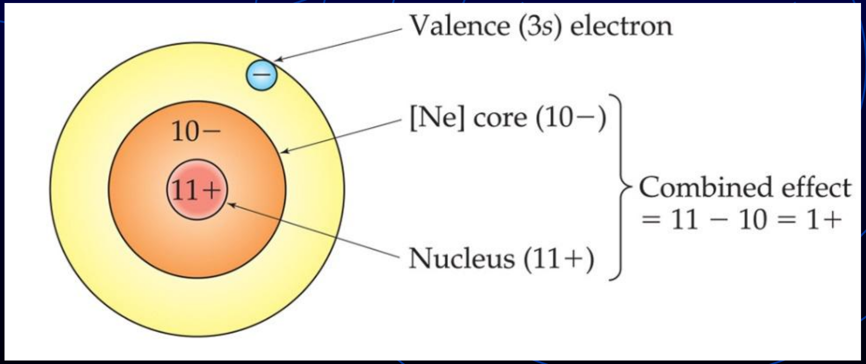
- Activity - Class as an atom
- Following the activity, predict the following:
- Smallest atom on the P.T.
- Largest atom
- Partner A: predict largest of Cl, Br, I
- Partner B: predict largest of B, Li or F
- Explain your prediction to your partner

Core Charge (CC)

Core charge is a measure of the attractive force on the **outer (valence)** electrons

Core Charge = (# protons) – (# inner electrons)

Calculate core charge for Na and Cl



Core Charge calculations

- CC_{Na} = 11-10= +1
- CC_{Cl} = 17-10= +7

- Effect on atomic radii?

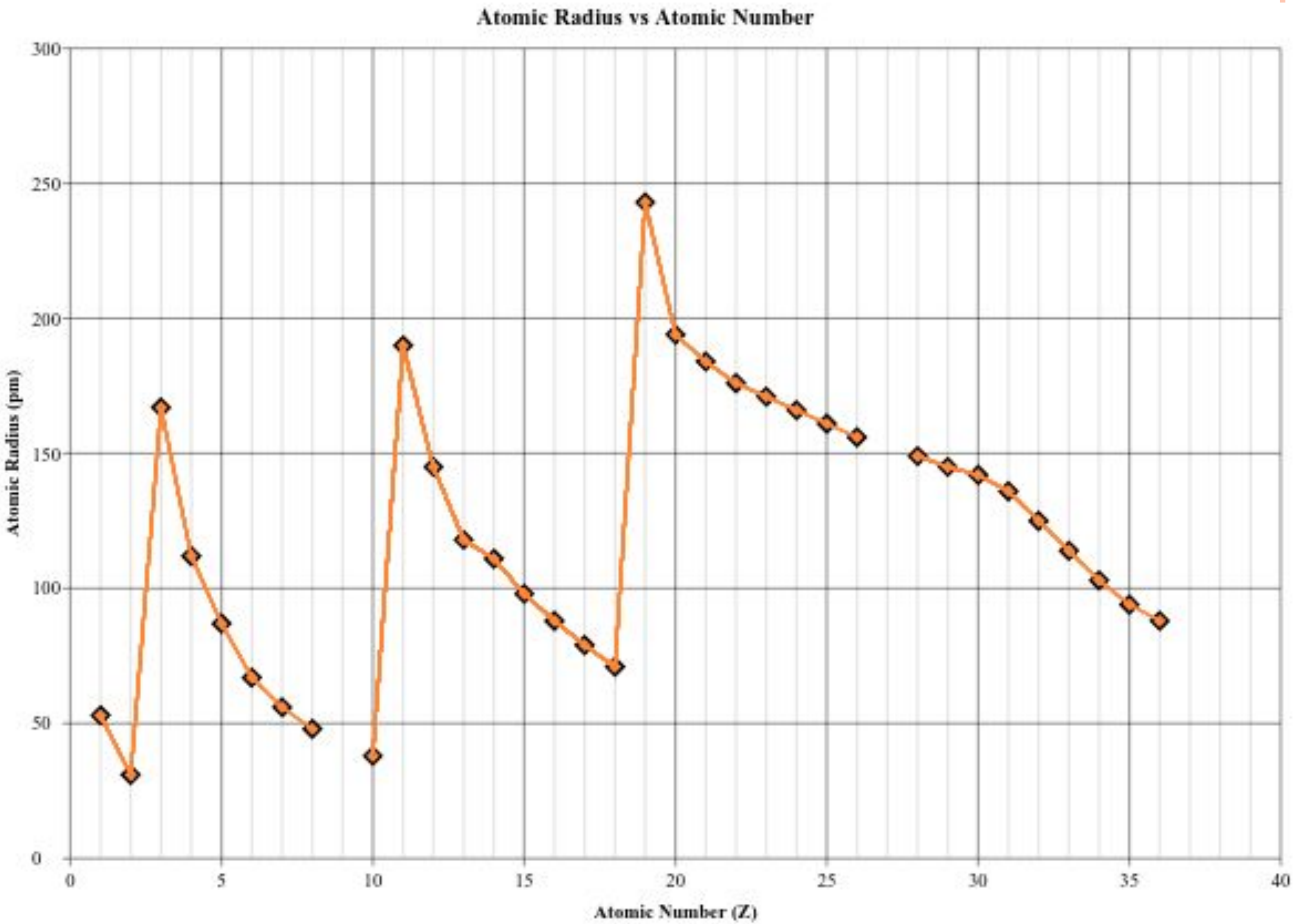
Homework

- Complete the predicted graph of atomic radii, noting positions of H, Li,Na and K
- WHAT ORDER SHOULD YOUR X-AXIS DATA BE IN?
- Complete Part 1 of Trends activity sheet
- Complete Trends question sheet #1-4

DAY 3

Your Graphing assignment

- Compare!
- What elements corresponded to the peaks?
- What elements corresponded to the troughs?
- What did you predict for F? Co? Rb?
- Any data that didn’t make sense (anomaly)?


Atomic Radius vs Atomic Number
Atomic Radius (pm)
0
50
100
150
200
250
300
0
5
10
15
20
25
30
35
40
Atomic Number (Z)

Ionization Energy

- Amount of energy (in kJ) required to remove an electron from the ground state of a gaseous atom or ion.

  Partner A: predict the trend across a period (will the energy increase to the left or to the right?). EXPLAIN.
  Partner B: Predict the trend down a group. Explain

Graphs

Have Atomic Radius Graph out for a signature

Complete Ionization graph.

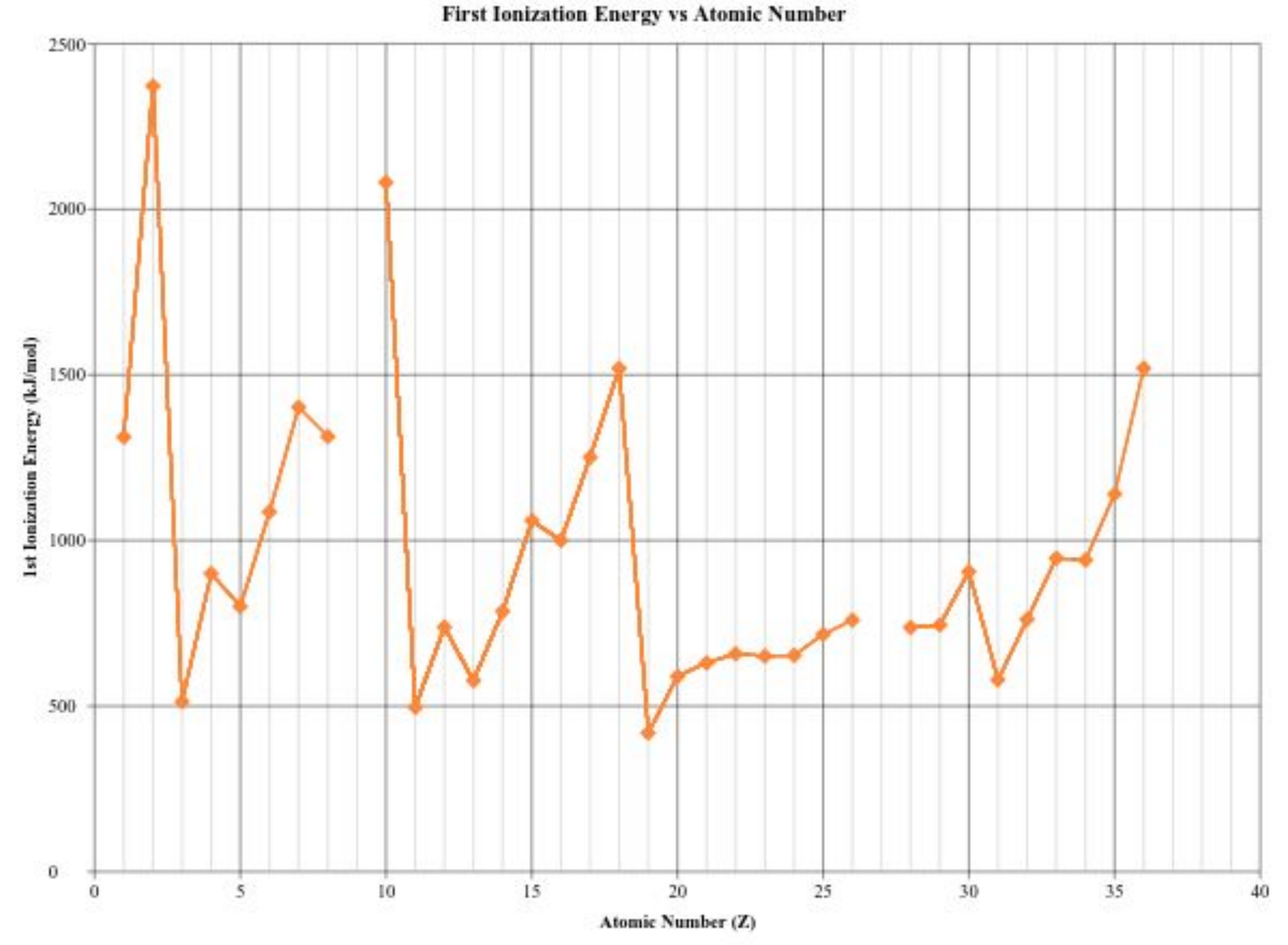
NOTES LIVE NOW TO PRINT FOR TOMORROW.

{Check I’ve made them live :) }

Day 4

Your I. E. Graph

- Looking at your graph:
  - Predictions for: F, Co and Rb


First Ionization Energy vs Atomic Number
1st Ionization Energy (kJ/mol)
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
40
Atomic Number (Z)

Shielding

- As more energy levels are added to atoms, the inner layers of electrons **shield** the outer electrons from the nucleus.
- The effective nuclear charge (Z_{eff}) on those outer electrons is less, and so the outer electrons are less tightly held.

Effective Nuclear Charge [Z_{eff}] (approximated using core charge)

- What keeps electrons from simply flying off into space?
- **Effective nuclear charge** is the pull that an electron "feels" from the nucleus.
- The closer an electron is to the nucleus, the more pull it feels.
- As effective nuclear charge increases, the electrons are pulled in tighter.

Atomic Radius Down a Group

- The trend for atomic radius in a vertical column is to go from smaller at the top to larger at the bottom of the family.
- Why?
- With each step down the family, we add an entirely new energy level to the electron cloud, making the atoms larger with each step.

Atomic Radius Across a Period

- The trend across a horizontal period is less obvious.
- What happens to atomic structure as we step from left to right?
- Each step adds a proton and an electron (and 1 or 2 neutrons).
- Electrons are added to existing energy levels.

Atomic Radius Across a Period

- The effect is that the more positive nucleus has a greater pull on the electron cloud.
- The nucleus is more positive and the electron cloud is more negative (slightly increased electron repulsion but not much).
- The **increased attraction pulls the cloud in**, making atoms smaller as we move from left to right across a period.

Predict Ionic radius

Partner A: How will cation radius compare to its neutral atom?

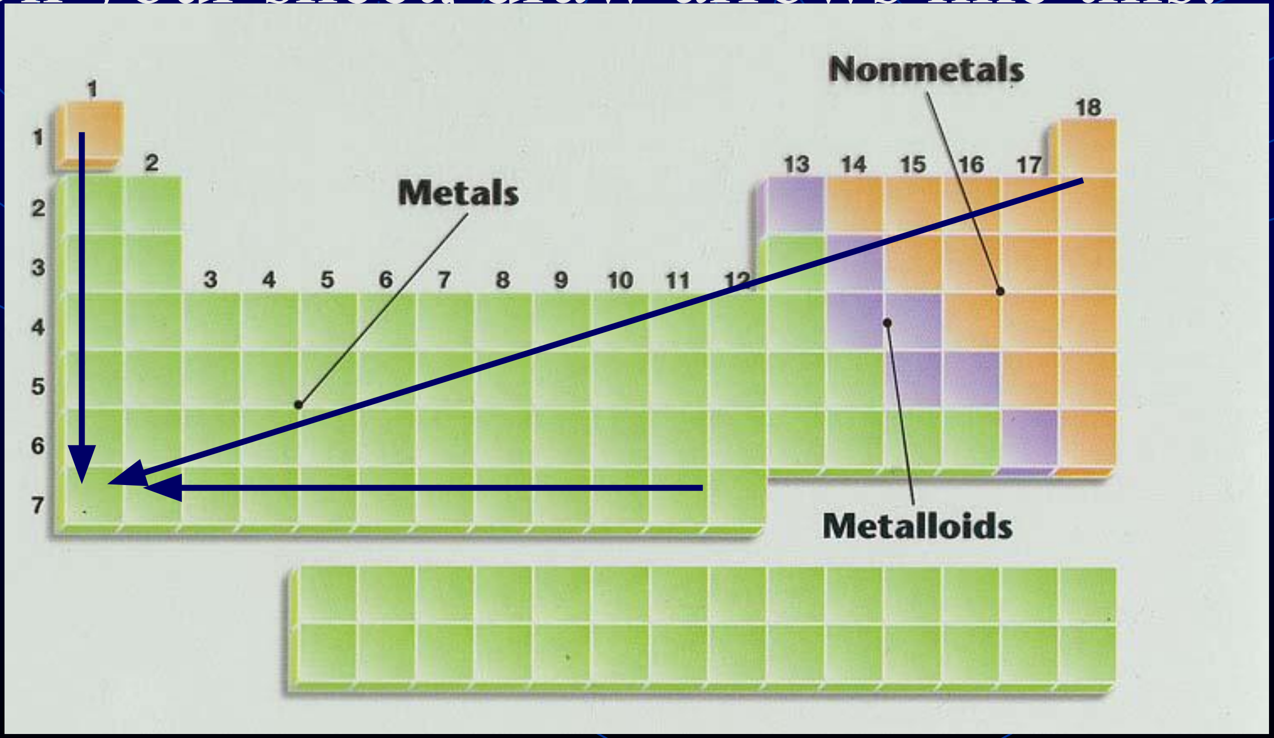
Partner B: How will anion radius compare to its neutral atom?

Ionic Radius

- Cations are always smaller than the original atom.
- The entire outer energy level is removed during ionization.
- Conversely, anions are always larger than the original atom.
- Electrons are added to the outer energy level, increasing electron repulsion and size.

Atomic Radius

- Here is an animation to explain the trend.
- Above doesn't work: try this next time (Tylre D) Video for Ionization Energy and Atomic Radius
- On your sheet, draw arrows like this:



Practice

- Which of the following would have the smallest atomic radius? Why?

Cl^{-}, S^{2-} , K^{+}, Ca^{2+} , Ar

Practice

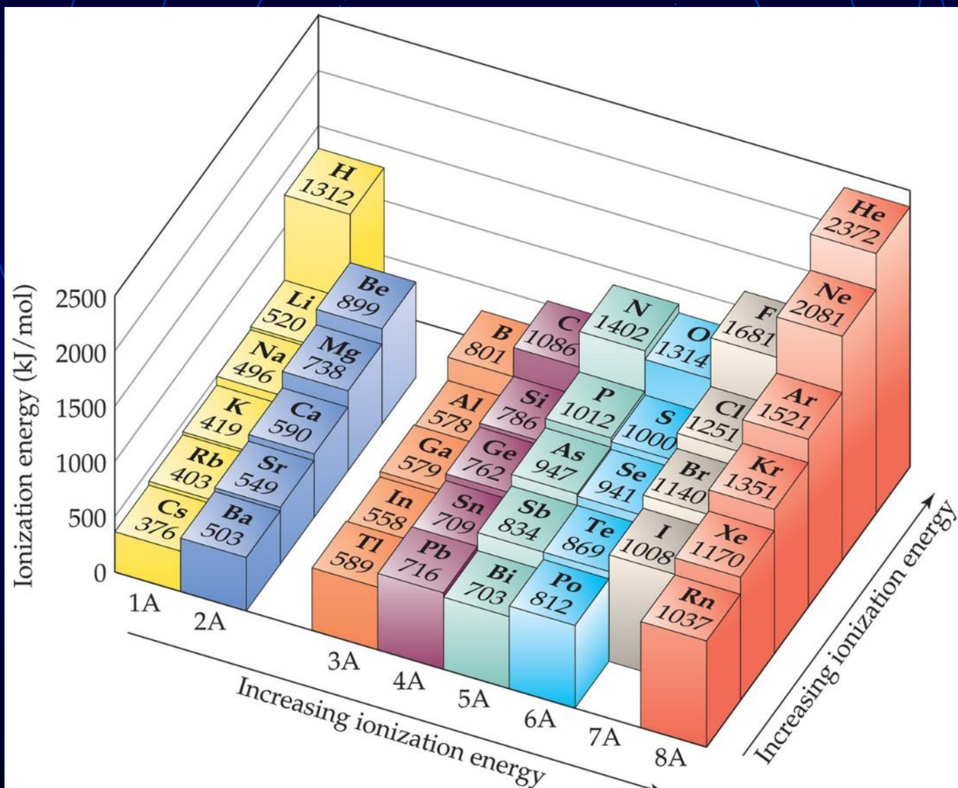
- Complete questions (with proper explanations) on the trends activity sheet
- Try questions 9 to 12 on the trends question sheet (ionic radius questions)

Predict!

- Using your knowledge of atomic size, will I.E. increase or decrease:
- A) Down groups
- B) across periods

- Complete the graph

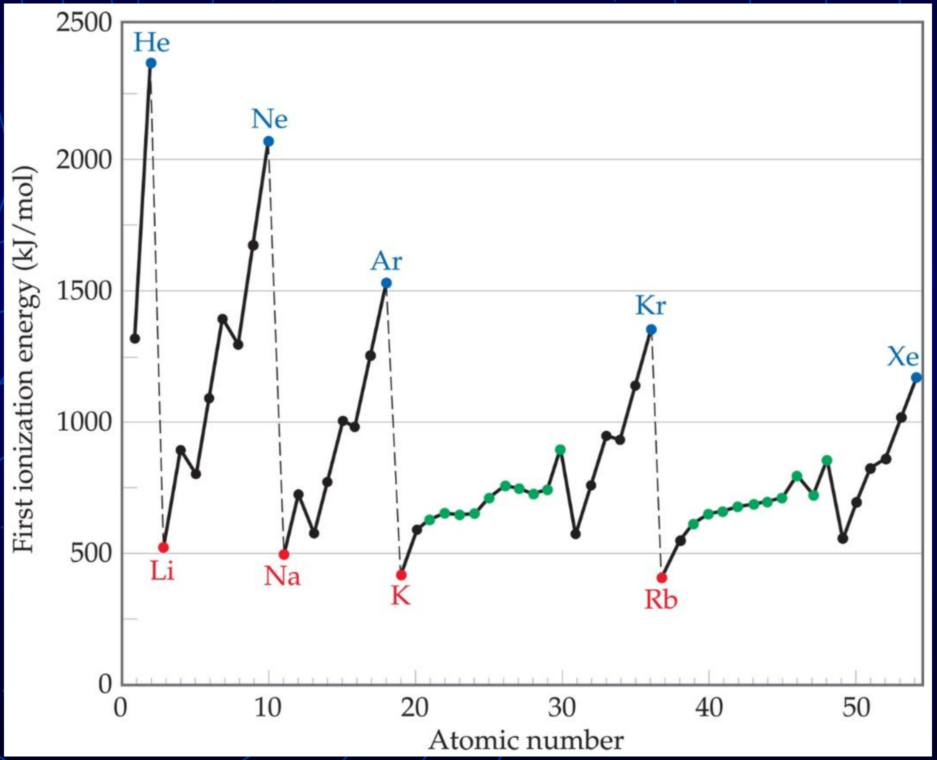
Trends in First Ionization Energies



- As one goes down a column, less energy is required to remove the first electron.
  - For atoms in the same group, Z_{eff} is essentially the same, but the valence electrons are farther from the nucleus.
  - More shielding

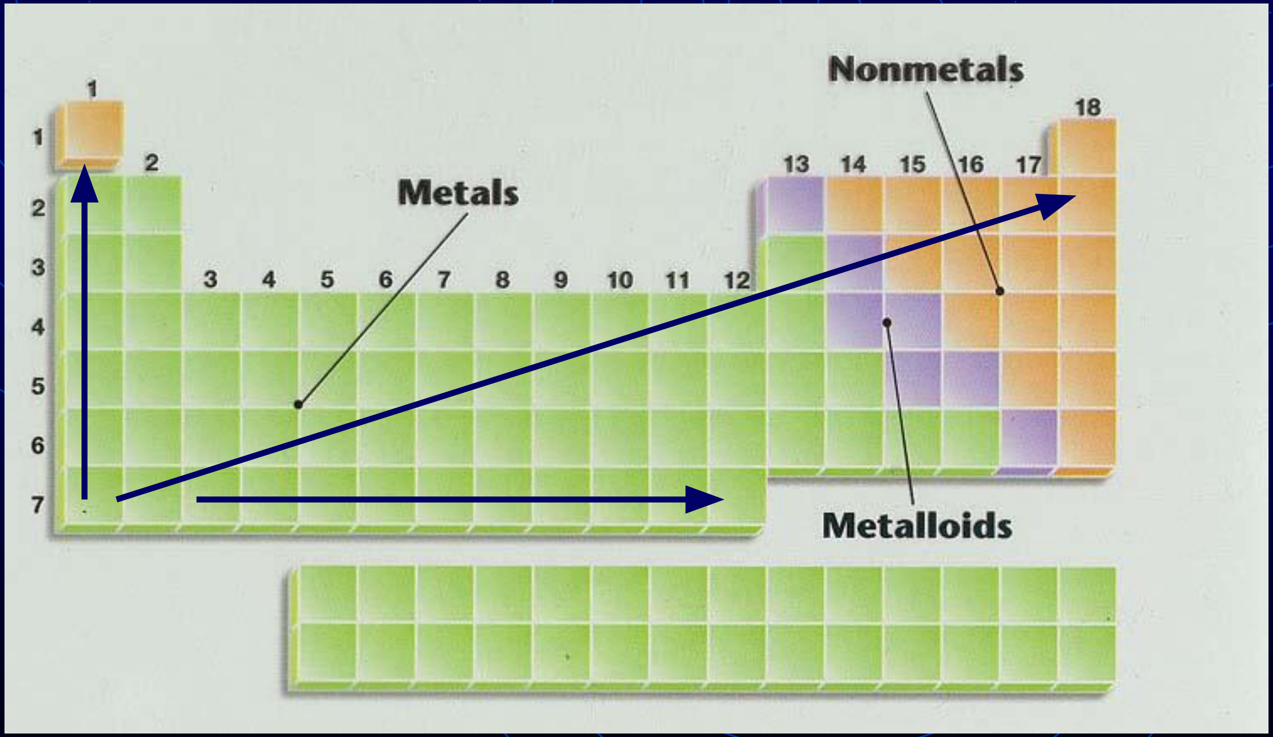
Trends in First Ionization Energies

- Generally, as one goes across a row, it gets harder to remove an electron.
    - As you go from left to right, Z_{eff} increases.
    - Atomic radii decreases so outer electrons are held more tightly



Ionization Energy (Potential)

- Draw arrows on your sheet like this:



This semester

Successive Ionization energy won't be covered. Do NOT complete questions #13-15 on Periodic Trends Question Sheet.

Successive Ionization Energy

- Amount of energy (in kJ) required to remove an electron from the ground state of a gaseous atom or ion.
  - First ionization energy is that energy required to remove first electron. [$Na_{(g)}$ + energy → $Na^{1+}_{(g)}$ + e^-]
  - Second ionization energy is that energy required to remove second electron, etc.
- The atom has been "ionized" or charged.
- The larger the atom is, the easier its electrons are to remove.

Successive Ionization Energies

- It requires more energy to remove each successive electron.
  - First ionization energy is that energy required to remove first electron. [$Na_{(g)}$ + energy → $Na^{1+}_{(g)}$ + e^{-}]
  - Second ionization energy is that required to remove second electron, etc.
- When all valence electrons have been removed, the ionization energy takes a large leap.

Element	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Na	495	4562			(inner-shell electrons)		
Mg	738	1451	7733				
Al	578	1817	2745	11,577			
Si	786	1577	3232	4356	16,091		
P	1012	1907	2914	4964	6274	21,267	
S	1000	2252	3357	4556	7004	8496	27,107
Cl	1251	2298	3822	5159	6542	9362	11,018
Ar	1521	2666	3931	5771	7238	8781	11,995

I.E. Calculations

An atom has the following ionization energies. Determine which group in the periodic table it belongs to.

$I.E._1 = 590$ kJ/mol $\quad$ $I.E._2 = 1145$ kJ/mol

$I.E._3 = 4936$ kJ/mol $\quad$ $I.E._4 = 6752$ kJ/mol

To determine this, you must identify the largest jump between successive ionization energies. You must divide a higher I.E. by the one that precedes it. Obviously this is not done for the first ionization energy since there is no preceding I.E.

I.E. Calculations

$I.E._2/I.E._1 = 1145/590 = 1.94$ $\rightarrow$ $I.E._2$ is ~ 2x $I.E._1$

$I.E._3/I.E._2 = 4936/1145 = 4.31$ $\rightarrow$ $I.E._3$ is ~ 4x $I.E._2$

$I.E._4/I.E._3 = 6752/4936 = 1.37$ $\rightarrow$ $I.E._4$ is <2x $I.E._3$

The biggest jump occurs between $I.E._2$ and $I.E._3$ and therefore $I.E._3$ is energy required to remove the electron from an inner energy level. Thus, $I.E._1$ and $I.E._2$ represent the energy required to remove electrons from the outer level; therefore, this atom has two outermost electrons and is in group 2 of the periodic table.

Day 5

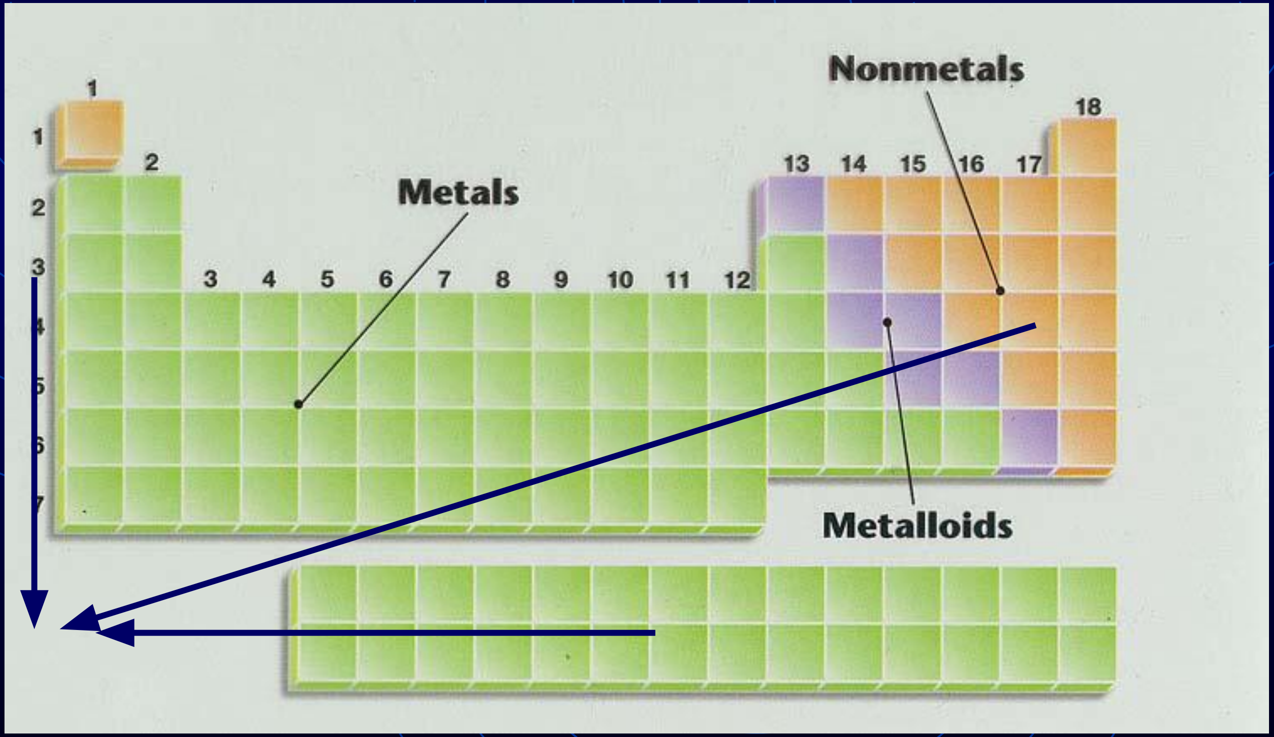
Trends and E.A lesson

ON YOUR WHITEBOARD

- without your notes, make a list of all factors that affect the trends (eg core charge)
-

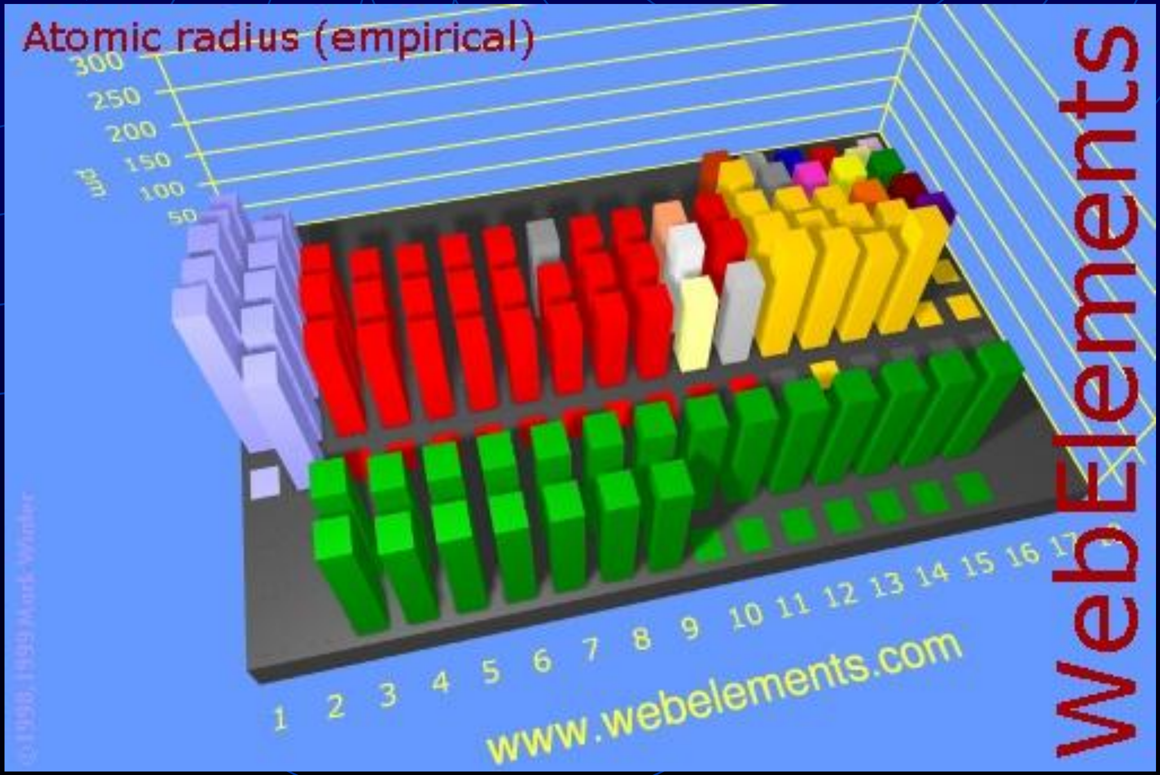
Atomic Radius

- Video for Ionization Energy and Atomic Radius
- On your sheet, draw arrows like this:



Atomic Radius

- The overall trend in atomic radius looks like this.



Electron Affinity
Predict the trend on whiteboard

- What does the word 'affinity' mean?
- Electron affinity is the energy **<u>change</u>** that occurs when an atom **<u>gains an electron</u>** (in kJ).

  $Cl + e^{-} \longrightarrow Cl^{-} + \text{energy}$

- Where ionization energy is always endothermic, electron affinity is usually exothermic → energy is released when an electron is added.

EA Trend down a group

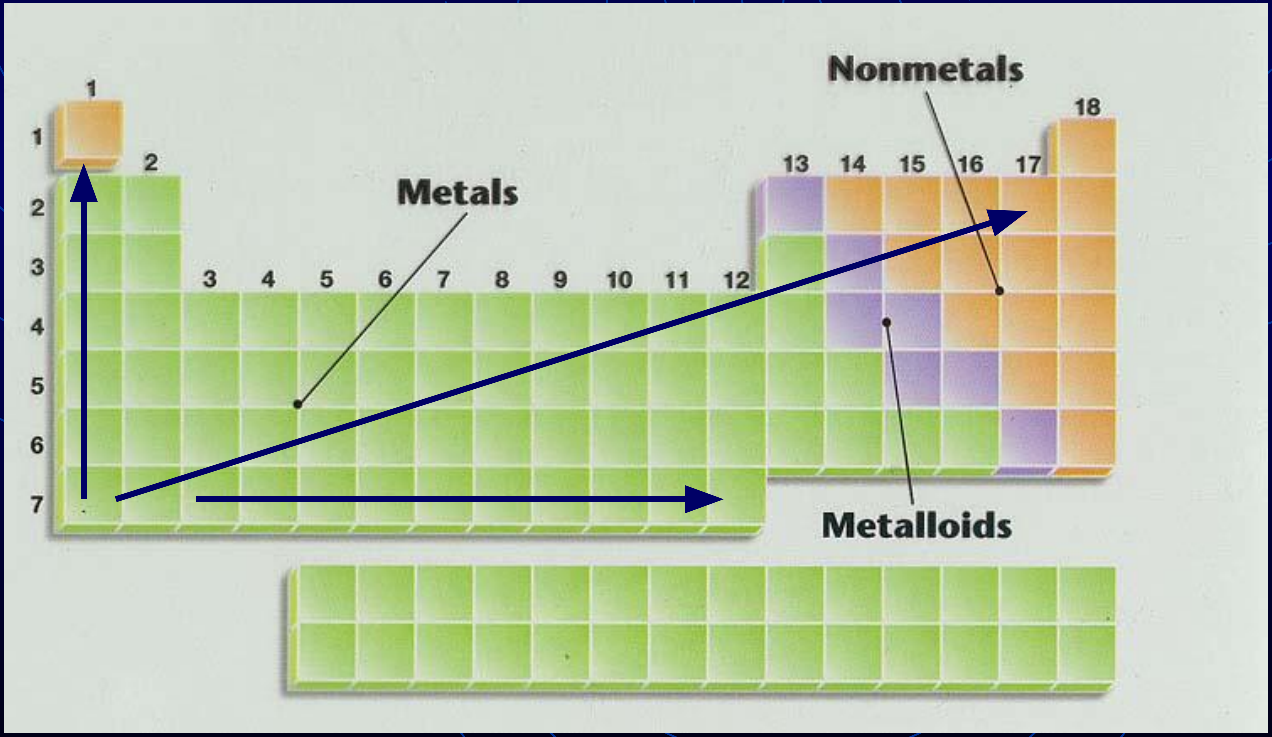
- Atoms further down a group have increasing resistance to receiving an extra electron and thus less positive electron affinities (E.A. becomes smaller)
- Increasing distance from the nucleus and shielding means the electron- electron repulsion increases when an extra electron is added for atoms further down the group

EA Trend across a period

- In general, electron affinity becomes more exothermic as you go from left to right across a row (easier to add an electron, more energy given off)
- Since there will be less nuclear force acting on the outermost electrons of elements to the left, electron-electron repulsion becomes more substantial when an electron is added to each atom.

Electron Affinity

- Your sheet should look like this:

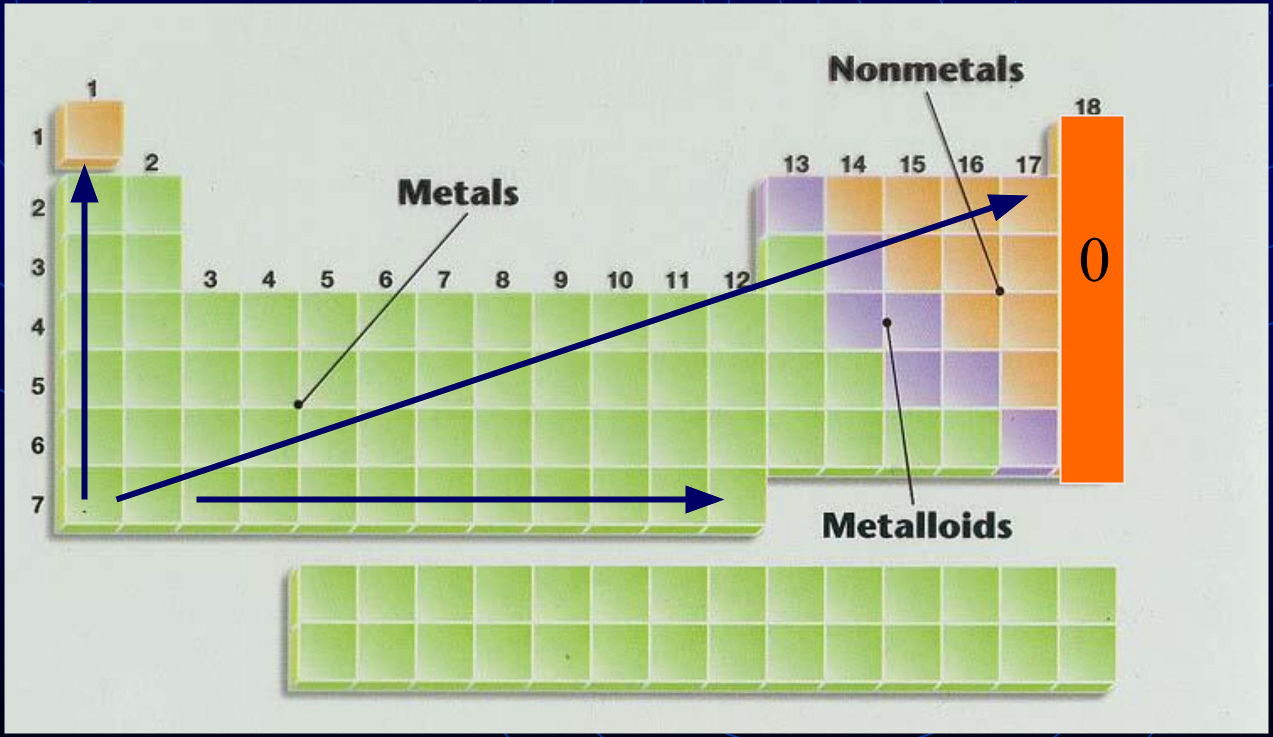


Electronegativity

- Electronegativity is a measure of an bonded atom's ability to attract electrons.
- It is an arbitrary scale that ranges from 0 to 4.
- The units of electronegativity are Paulings.
- Generally, metals are electron givers and have low electronegativities.
- Nonmetals are electron takers and have high electronegativities.
- What about the noble gases?

Electronegativity

- Your sheet should look like this:

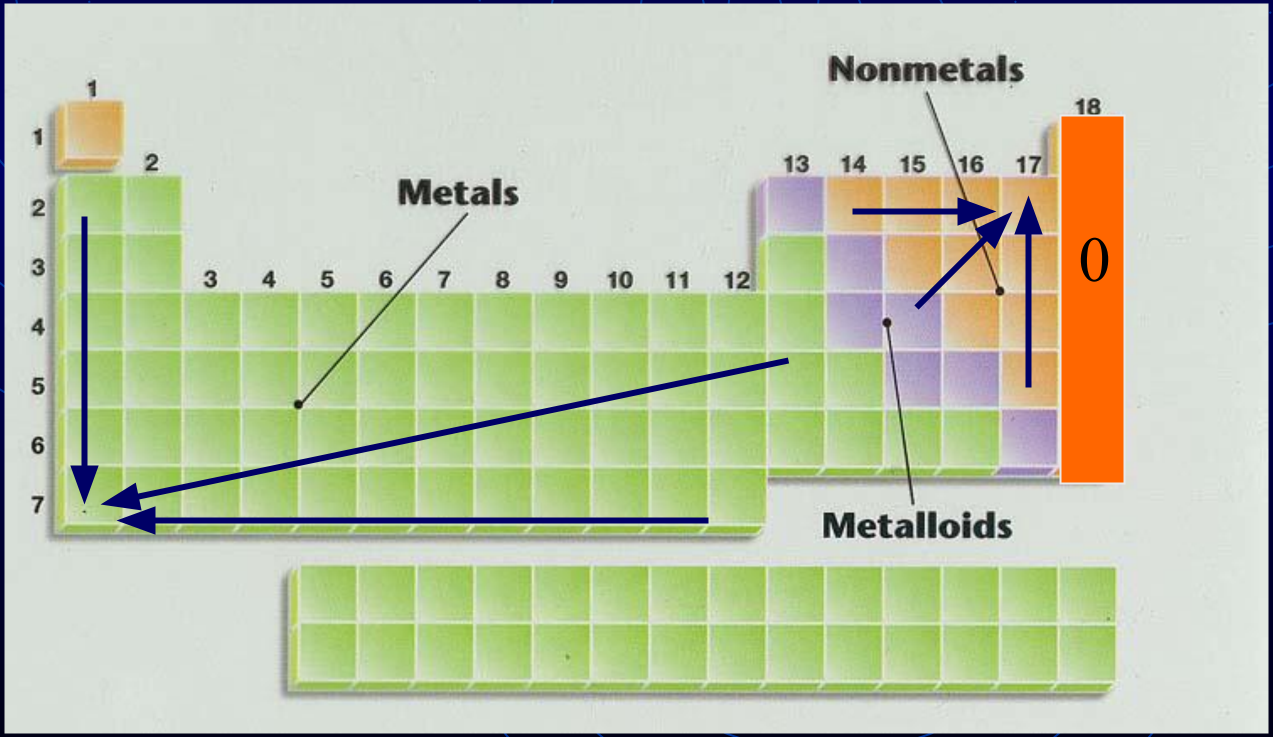


Overall Reactivity

- This ties all the previous trends together in one package.
- However, we must treat metals and nonmetals separately.
- The most reactive metals are the largest since they are the best electron givers.
- The most reactive nonmetals are the smallest ones, the best electron takers.

Overall Reactivity

- Your summary sheet will look like this:



The End

Moving across a period

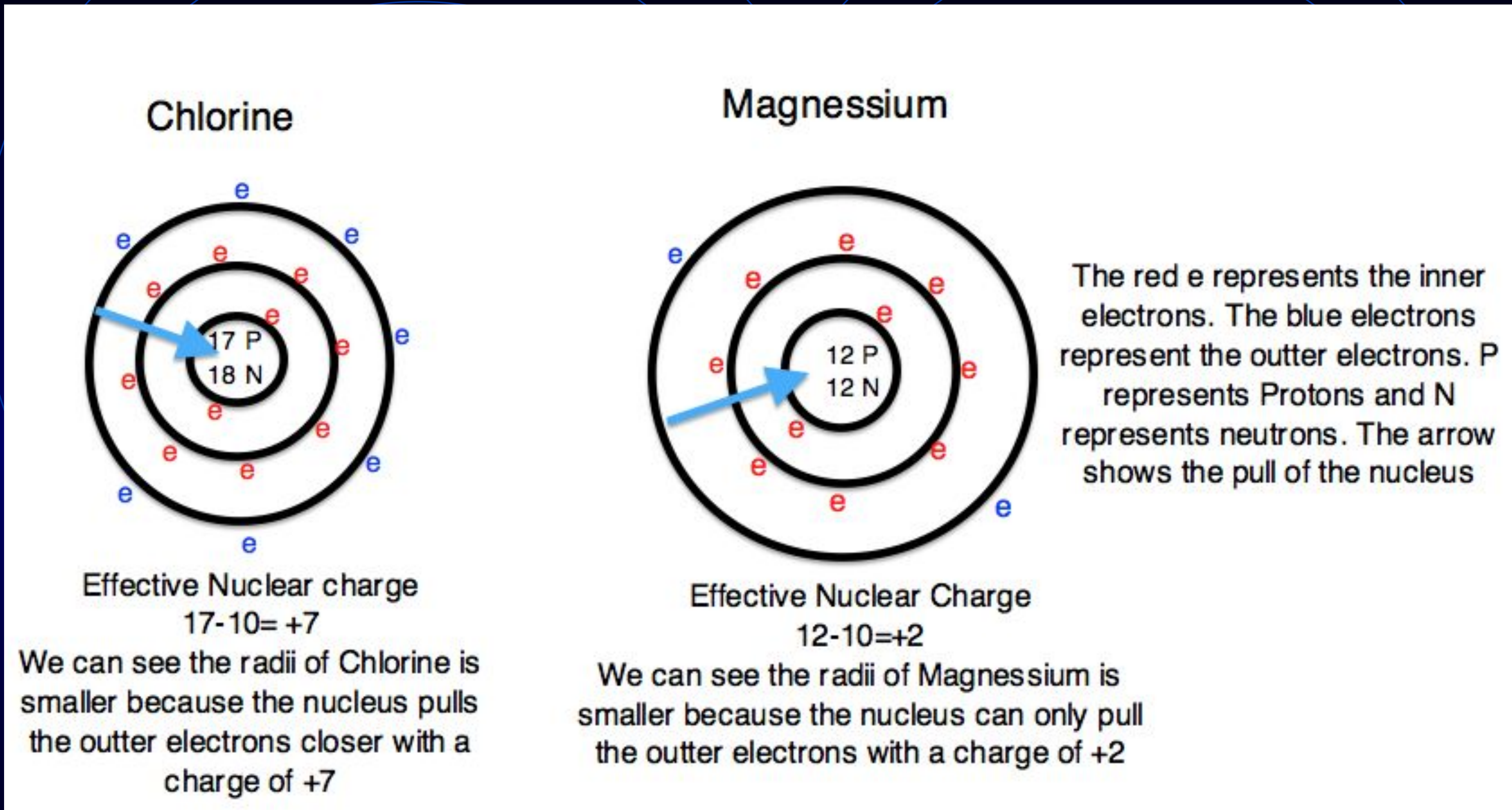
Answer: AR decreases

- What is the same:
  - # of inner electrons
- What is changing:
  - Zeff increasing (more attraction)
  - e-e repulsion increasing with each addition, but only slightly
- Overall: attractive force is greater, resulting in a decrease

Moving down a group

Atomic Radius increases

- What is the same:
  - Zeff
  - e-e repulsion in outer shell
- What is changing:
  - Number of inner complete shells: contributes a lot to e-e repulsion (shielding effect)
  - Overall: repulsion is greater, resulting in a increase in AR



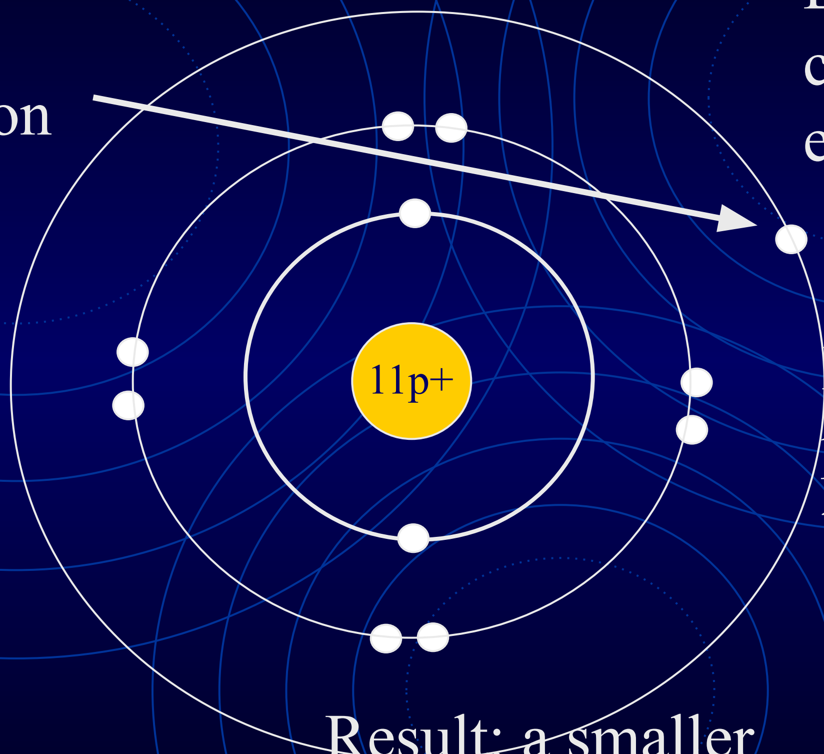
http://chemwiki.ucdavis.edu/@api/deki/files/1175/effective_nuclear_charge.png?size=bestfit&width=614&height=328&revision=1

Cation Formation

Na atom

1 valence electron

Effective nuclear charge on remaining electrons increases.



Remaining e- are pulled in closer to the nucleus. Ionic size decreases.

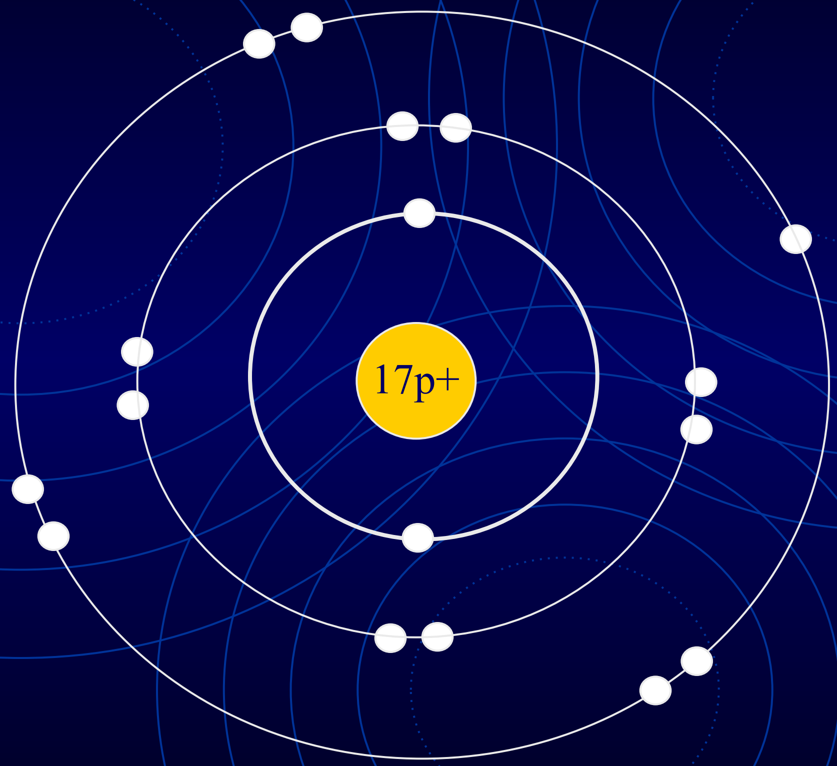
Valence e- lost in ion formation

Result: a smaller sodium cation, Na^+

Anion Formation

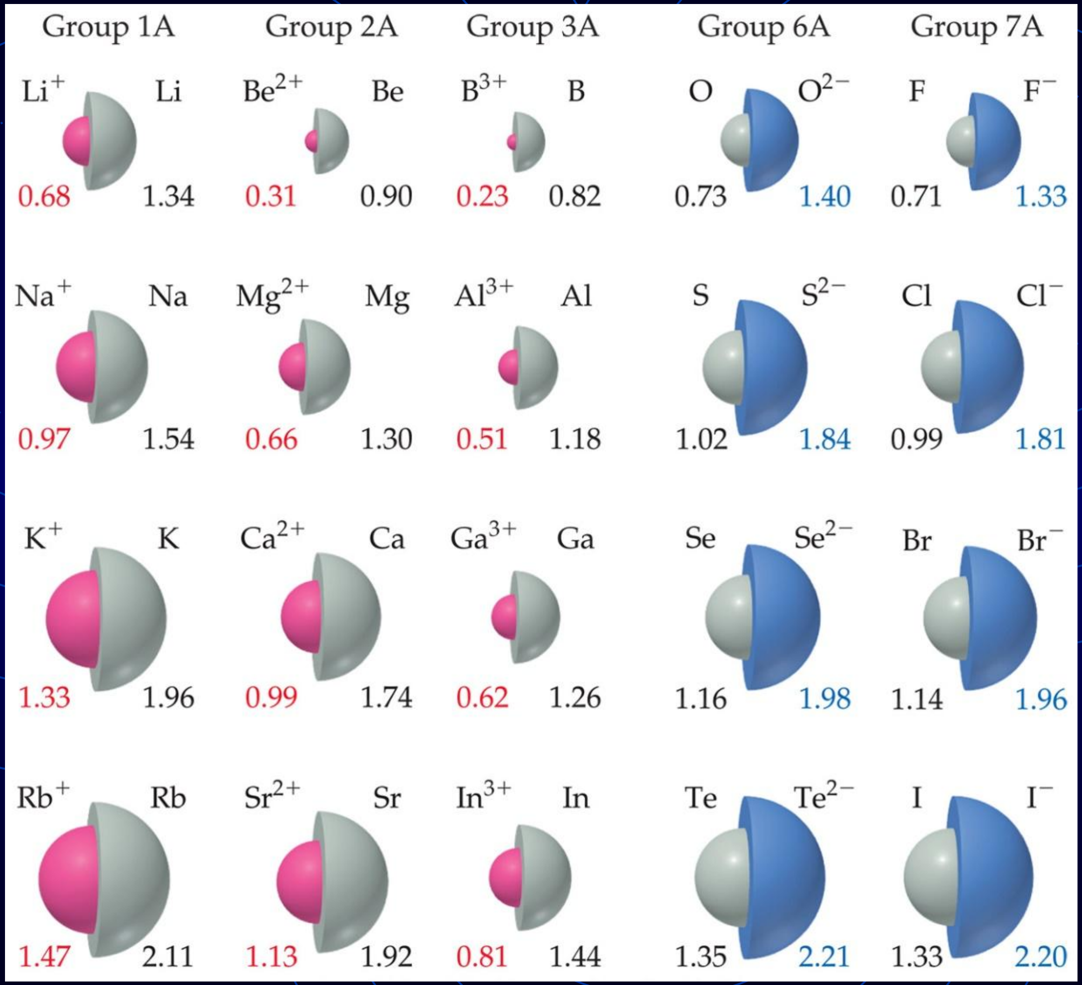
A chloride ion is produced. It is larger than the original atom.

Chlorine atom with 7 valence e-



One e- is added to the outer shell.

Effective nuclear charge is reduced and the e- cloud expands.


Group 1A
Group 2A
Group 3A
Group 6A
Group 7A
Li+ Li 0.68 1.34
Be2+ Be 0.31 0.90
B3+ B 0.23 0.82
O O2− 0.73 1.40
F F− 0.71 1.33
Na+ Na 0.97 1.54
Mg2+ Mg 0.66 1.30
Al3+ Al 0.51 1.18
S S2− 1.02 1.84
Cl Cl− 0.99 1.81
K+ K 1.33 1.96
Ca2+ Ca 0.99 1.74
Ga3+ Ga 0.62 1.26
Se Se2− 1.16 1.98
Br Br− 1.14 1.96
Rb+ Rb 1.47 2.11
Sr2+ Sr 1.13 1.92
In3+ In 0.81 1.44
Te Te2− 1.35 2.21
I I− 1.33 2.20