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The Periodic Table and Chemical Periodicity

HS Chemistry Rapid Learning Series

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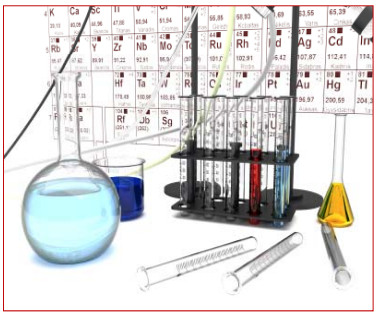
Learning Objectives

By completing this tutorial you will learn…



- The organization of the periodic table.
- How properties of an element can be determined from trends of the periodic table.
- How electronegativity, ionization energy, electron affinity relate to atomic radii.
- How ionic radii relates to atomic radii.

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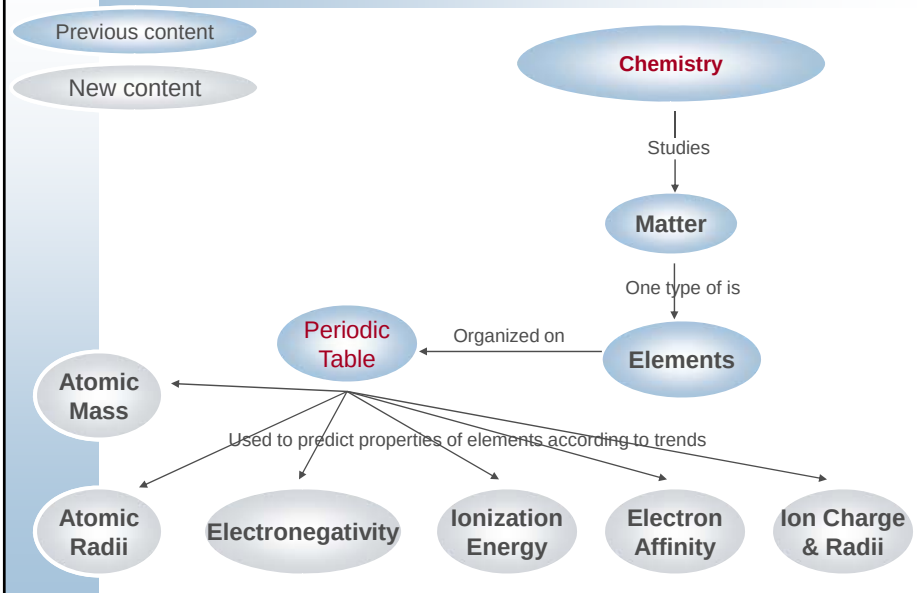
Concept Map



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History of the Periodic Table

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Development of the Modern Table

Scientists went through many revisions to arrive at the current Periodic Table.

Many scientists organized the elements in different ways.	These systems had various flaws.
Mendeleev organized the elements by atomic mass in rows/columns according to properties.	Some holes were left if no known element had the properties needed to fit the pattern.
More elements were discovered.	The holes were filled in.
Elements were re-organized by atomic number.	A couple of elements switched places.

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Organization of the Periodic Table of Elements

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Definition: Periodic Table

Periodic Table – A tool used by chemists. Organizes the elements and provides information about them.

Elements are organized by increasing order of atomic number.

The atomic number is the number of protons and determines the identity of the atom.

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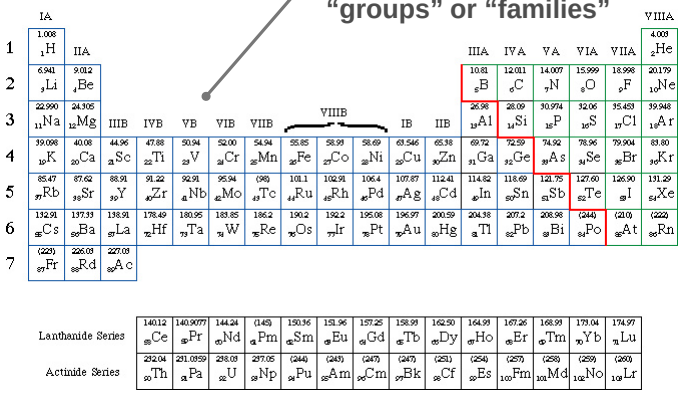
Groups and Periods

The periodic table is organized by:

Groups
Columns are called "groups" or "families"

Periods
Rows are called "periods"



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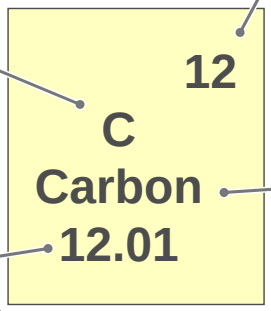
Information for Each Element

Most periodic tables give the following information, but it can be in a different location.

Atomic Number
Whole number—elements are ordered by this on the periodic table.

Element Symbol
If there's a second letter, it's lower-case.



Element Name

Atomic Mass
Number with decimals. Give the mass for 1 mole of atoms.

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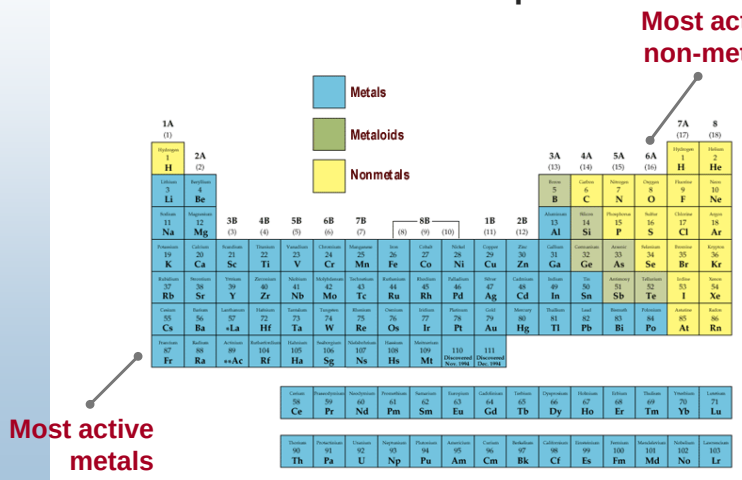
Metals and Non-Metals

The stair-step separates the metals & non-metals. Metalloids touch the stair-step.



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Properties of Metals and Non-Metals

There are several characteristics of each type of element:

Metals	Non-Metals	Metalloids
High electrical conductivity	Low electrical conductivity	Have properties of both metals and non-metals
High melting points	Low melting points	
Malleable & ductile	Brittle	

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How to Memorize the Elements 1-20

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Mnemonic for the First 20 Elements

	IA												IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 $_{1}$H	IIA						VIIIB		IB	IIB							4.003 $_{2}$He
2	6.941 $_{3}$Li	9.012 $_{4}$Be											10.81 $_{5}$B	12.011 $_{6}$C	14.007 $_{7}$N	15.999 $_{8}$O	18.998 $_{9}$F	20.179 $_{10}$Ne
3	22.990 $_{11}$Na	24.305 $_{12}$Mg	IIIB	IVB	VB	VIB	VIIB						26.98 $_{13}$Al	28.09 $_{14}$Si	30.974 $_{15}$P	32.05 $_{16}$S	35.453 $_{17}$Cl	39.948 $_{18}$Ar
4	39.098 $_{19}$K	40.08 $_{20}$Ca	44.96 $_{21}$Sc	47.88 $_{22}$Ti	50.94 $_{23}$V	52.00 $_{24}$Cr	54.94 $_{25}$Mn	55.85 $_{26}$Fe	58.93 $_{27}$Co	58.69 $_{28}$Ni	63.546 $_{29}$Cu	65.38 $_{30}$Zn	69.72 $_{31}$Ga	72.59 $_{32}$Ge	74.92 $_{33}$As	78.96 $_{34}$Se	79.904 $_{35}$Br	83.80 $_{36}$Kr
5	85.47 $_{37}$Rb	87.62 $_{38}$Sr	88.91 $_{39}$Y	91.22 $_{40}$Zr	92.91 $_{41}$Nb	95.94 $_{42}$Mo	(98) $_{43}$Tc	101.1 $_{44}$Ru	102.91 $_{45}$Rh	106.4 $_{46}$Pd	107.87 $_{47}$Ag	112.41 $_{48}$Cd	114.82 $_{49}$In	118.69 $_{50}$Sn	121.75 $_{51}$Sb	127.60 $_{52}$Te	126.90 $_{53}$I	131.29 $_{54}$Xe
6	132.91 $_{55}$Cs	137.33 $_{56}$Ba	138.91 $_{57}$La	178.49 $_{72}$Hf	180.95 $_{73}$Ta	183.85 $_{74}$W	186.2 $_{75}$Re	190.2 $_{76}$Os	192.2 $_{77}$Ir	195.08 $_{78}$Pt	196.97 $_{79}$Au	200.59 $_{80}$Hg	204.38 $_{81}$Tl	207.2 $_{82}$Pb	208.98 $_{83}$Bi	(244) $_{84}$Po	(210) $_{85}$At	(222) $_{86}$Rn
7	(223) $_{87}$Fr	226.03 $_{88}$Rd	227.03 $_{89}$A c															

Happy Henry, The Little Beach Boy, CaN dO FiNe

Naughty Megan, the Alpine

Sister, Pretends to Ski at ClArK Canyon

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Periodicity

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Definition: Periodicity

Periodicity of the Periodic Table – The predictable pattern by which properties of elements change across or down the periodic table.

There are always exceptions to these periodicity trends… each of the trends is a "general" trend as you move across a period or down a group.

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Atomic Mass

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Definition: Atomic Mass

Atomic Mass – the mass in grams for 6.02×10^{23} atoms. Found on the periodic table.

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Atomic Mass Trends

In general, the atomic mass:

Increases

Increases

	IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	1.008 $_{1}H$															4.003 $_{2}He$
2	6.941 $_{3}Li$	9.012 $_{4}Be$									10.81 $_{5}B$	12.011 $_{6}C$	14.007 $_{7}N$	15.999 $_{8}O$	18.998 $_{9}F$	20.179 $_{10}Ne$
3	22.990 $_{11}Na$	24.305 $_{12}Mg$									26.98 $_{13}Al$	28.09 $_{14}Si$	30.974 $_{15}P$	32.06 $_{16}S$	35.453 $_{17}Cl$	39.948 $_{18}Ar$
4	39.098 $_{19}K$	40.08 $_{20}Ca$	44.96 $_{21}Sc$	47.88 $_{22}Ti$	50.94 $_{23}V$	52.00 $_{24}Cr$	54.94 $_{25}Mn$	55.85 $_{26}Fe$	58.93 $_{27}Co$	58.69 $_{28}Ni$	63.546 $_{29}Cu$	65.38 $_{30}Zn$	69.72 $_{31}Ga$	72.59 $_{32}Ge$	74.92 $_{33}As$	78.96 $_{34}Se$	79.904 $_{35}Br$	83.80 $_{36}Kr$
5	85.47 $_{37}Rb$	87.62 $_{38}Sr$	88.91 $_{39}Y$	91.22 $_{40}Zr$	92.91 $_{41}Nb$	95.94 $_{42}Mo$	(98) $_{43}Tc$	101.1 $_{44}Ru$	102.91 $_{45}Rh$	106.4 $_{46}Pd$	107.87 $_{47}Ag$	112.41 $_{48}Cd$	114.82 $_{49}In$	118.69 $_{50}Sn$	121.75 $_{51}Sb$	127.60 $_{52}Te$	126.90 $_{53}I$	131.29 $_{54}Xe$
6	132.91 $_{55}Cs$	137.33 $_{56}Ba$	138.91 $_{57}La$	178.49 $_{72}Hf$	180.95 $_{73}Ta$	183.85 $_{74}W$	186.2 $_{75}Re$	190.2 $_{76}Os$	192.2 $_{77}Ir$	195.08 $_{78}Pt$	196.97 $_{79}Au$	200.59 $_{80}Hg$	204.38 $_{81}Tl$	207.2 $_{82}Pb$	208.98 $_{83}Bi$	(244) $_{84}Po$	(210) $_{85}At$	(222) $_{86}Rn$
7	(223) $_{87}Fr$	226.03 $_{88}Rd$	227.03 $_{89}Ac$															

Lanthanide Series	140.12 $_{58}Ce$	140.9077 $_{59}Pr$	144.24 $_{60}Nd$	(145) $_{61}Pm$	150.36 $_{62}Sm$	151.96 $_{63}Eu$	157.25 $_{64}Gd$	158.93 $_{65}Tb$	162.50 $_{66}Dy$	164.93 $_{67}Ho$	167.26 $_{68}Er$	168.93 $_{69}Tm$	173.04 $_{70}Yb$	174.97 $_{71}Lu$
Actinide Series	232.04 $_{90}Th$	231.0359 $_{91}Pa$	238.03 $_{92}U$	237.05 $_{93}Np$	(244) $_{94}Pu$	(243) $_{95}Am$	(247) $_{96}Cm$	(247) $_{97}Bk$	(251) $_{98}Cf$	(254) $_{99}Es$	(257) $_{100}Fm$	(258) $_{101}Md$	(259) $_{102}No$	(260) $_{103}Lr$

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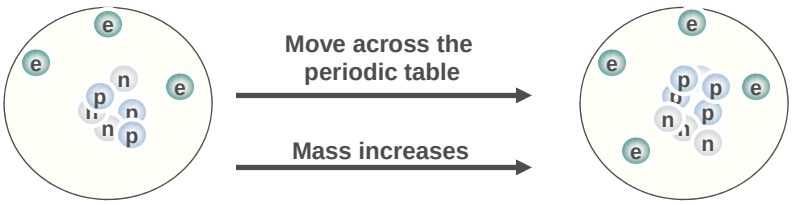
Atomic Mass Trends Reasoning

Why does atomic mass increase across a period?

Moving left to right, the number of protons, neutrons and electrons all increase.
More subatomic particles leads to higher mass.

Why does atomic mass increase down a group?

For the same reason as above!



Lithium atom

Beryllium atom

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Atomic Radii

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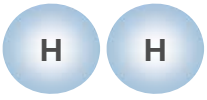
Definition: Atomic Radius

Atomic Radius – Half of the distance between the nuclei of two bonded atoms.



Distance between nuclei

Atomic radius of hydrogen atom

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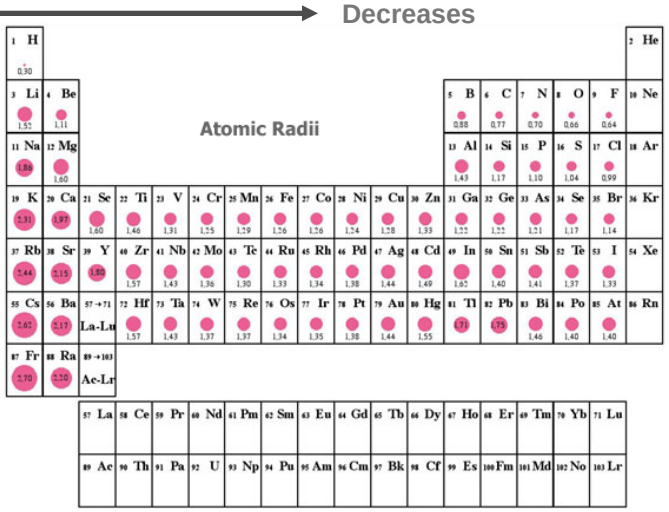
Atomic Radii Trends

In general, atomic radii:

Decreases

Increases



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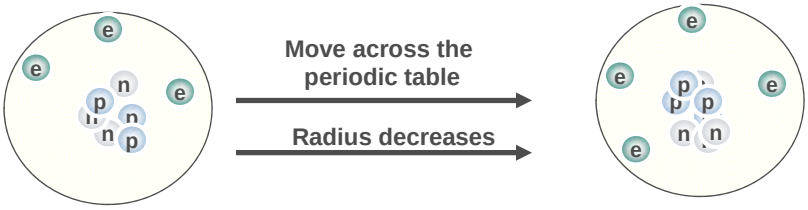
Atomic Radii Trends Reasoning, Part 1

Why does atomic radii decrease across a period?

Moving left to right, the number of protons, neutrons and electrons all increase.



Lithium atom

Beryllium atom

As the # of protons and electrons increase, the attraction between the positive nucleus and negative electron cloud increases.

This attraction "pulls" in on the electrons.

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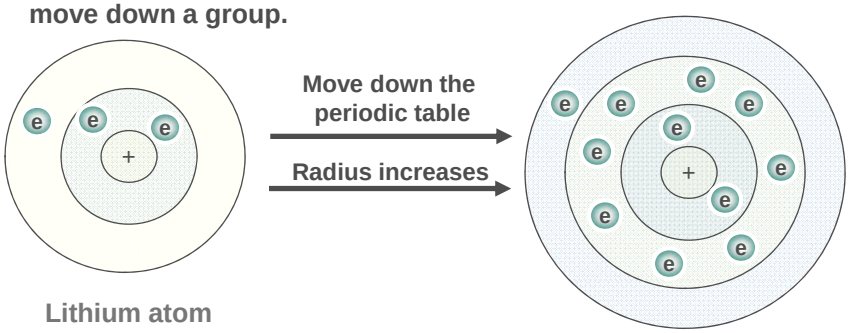
Atomic Radii Trends Reasoning, Part 2

Why does atomic radii increase down a group?

Protons, neutrons and electrons are also added as you move down a group.



However, the electrons are added in new energy levels.

The inner electrons “shield” the new outer electrons from the pull of the nucleus, therefore it doesn’t pull in like the last slide

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Electronegativity

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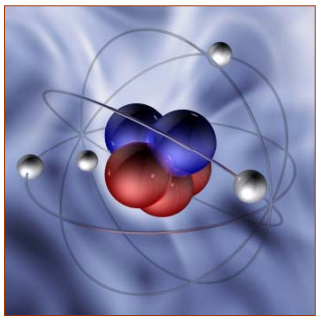
Definition: Electronegativity

Electronegativity – The pull an atom has on the electrons it shares in a bond with another atom.



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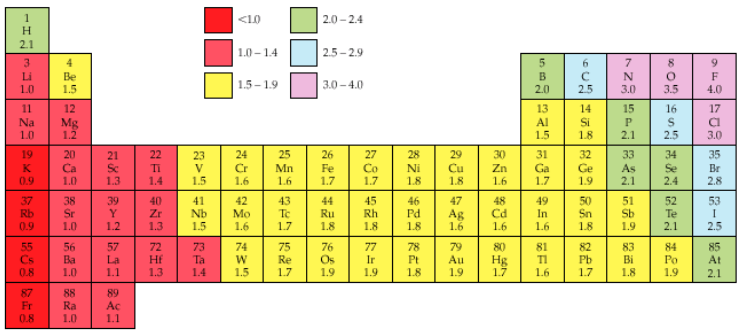
Electronegativity Trends

In general, electronegativity:

Increases

Decreases

Electronegativity Values for the Elements



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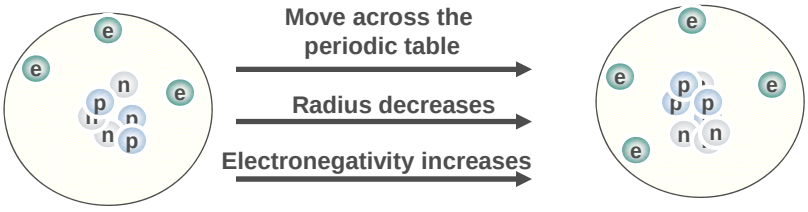
Electronegativity Trends Reasoning - 1

Why does electronegativity increase across a period?

Moving left to right, the radius of the atom decreases as more protons pull on more electrons.



Lithium atom

Beryllium atom

When an atom is smaller, the electrons are closer to the nucleus, and therefore feel the pull more strongly.

Smaller atoms will have a higher electronegativity.

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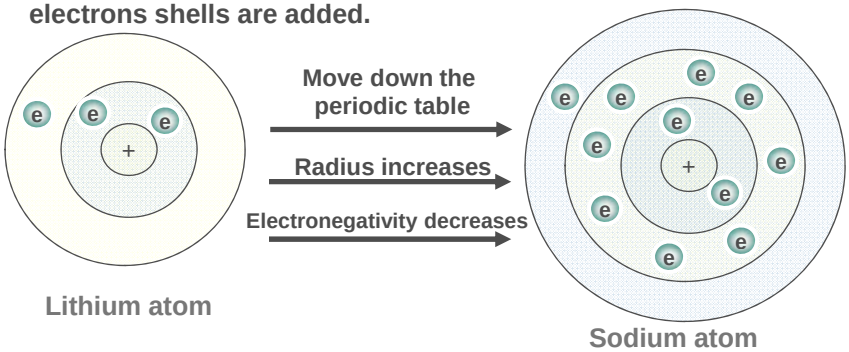
Electronegativity Trends Reasoning - 2

Why does electronegativity decrease down a group?

As you move down a group, the radius increases as more electrons shells are added.



Lithium atom

Sodium atom

As the outer electrons (those involved in bonding) are farther from the nucleus, they will feel the "pull" of the nucleus less.

Larger atoms have lower electronegativity.

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Ionization Energy

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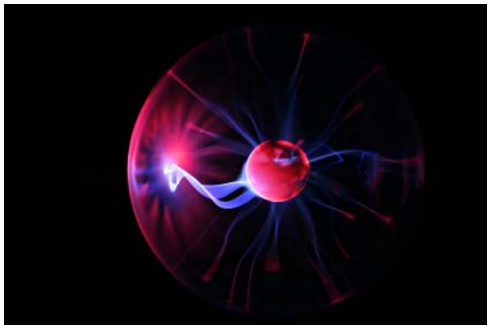
Definition: Ionization Energy

Ionization energy – The energy needed to remove the outermost electron.



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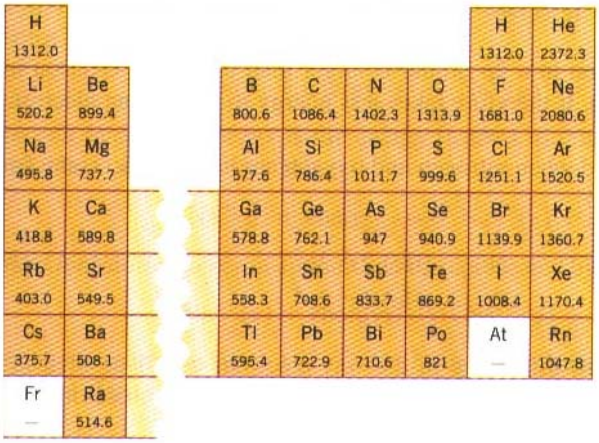
Ionization Energy Trends

In general, Ionization Energy:

Increases

Decreases



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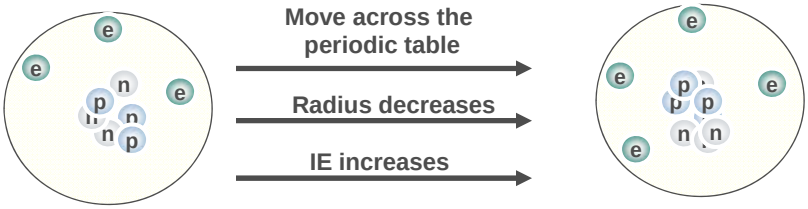
Ionization Energy Trends Reasoning, Part 1

Why does Ionization Energy increase across a period?

Moving left to right, the radius of the atom decreases as more protons pull on more electrons.



Lithium atom

Beryllium atom

When an atom is smaller, the electrons are closer to the nucleus, and therefore feel the pull more strongly.

It is harder to pull electrons away from these smaller atoms.

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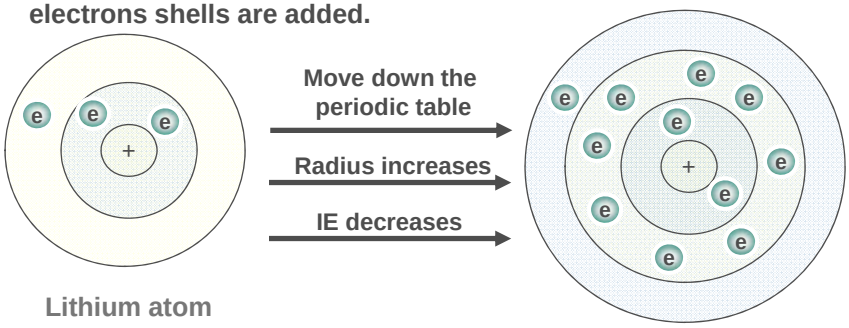
Electronegativity Trends Reasoning, Part 2

Why does electronegativity decrease down a group?

As you move down a group, the radius increases as more electrons shells are added.



As the outer electrons (those involved in bonding) are farther from the nucleus, they will feel the "pull" of the nucleus less.

It is easier to remove an electron from a larger atom.

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Electron Affinity

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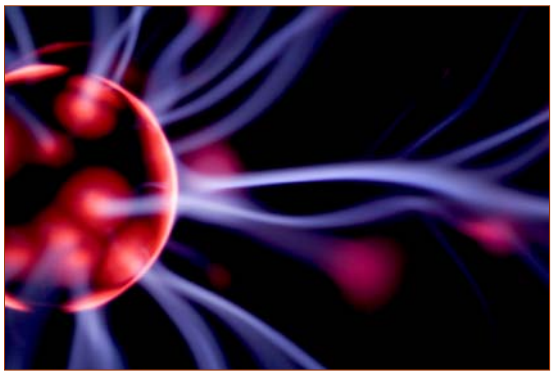
Definition: Electron Affinity

Electron Affinity – The energy released when an electron is added to an atom.



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Electron Affinity Trends

In general, electron affinity:

Increases

Decreases

IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
H 73.5						H 73.5	He *
Li 60.4	Be *	B 27	C 123.4	N -7	O 142.5	F 331.4	Ne *
Na 53.2	Mg *	Al 46	Si 135.0	P 72.4	S 202.5	Cl 352.4	Ar *
K 48.9	Ca *	Ga 30	Ge 120	As 78	Se 197.0	B 327.9	Kr *
Rb 47.4	Sr *	In 29	Sn 122	Sb 102	Te 192.1	I 298.4	Xe *
Cs 46.0	Ba *	Tl 30	Pb 110	Bi 110	Po 190	At 270	Rn *
Fr 44.5	Ra *						

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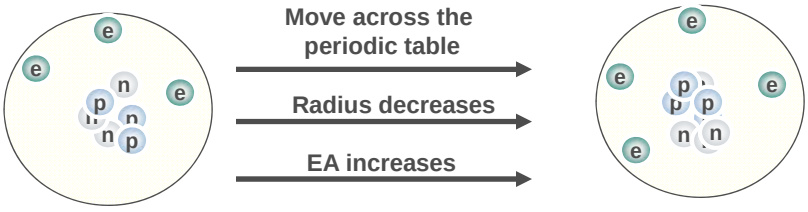
Electron Affinity Trends Reasoning - 1

Why does Electron Affinity increase across a period?

Moving left to right, the radius of the atom decreases as more protons pull on more electrons.



Lithium atom

Beryllium atom

When an atom is smaller, the electrons are closer to the nucleus, and therefore feel the pull more strongly.

A smaller atom can handle an extra electron more easily as it can be more "controlled" by the closer nucleus.

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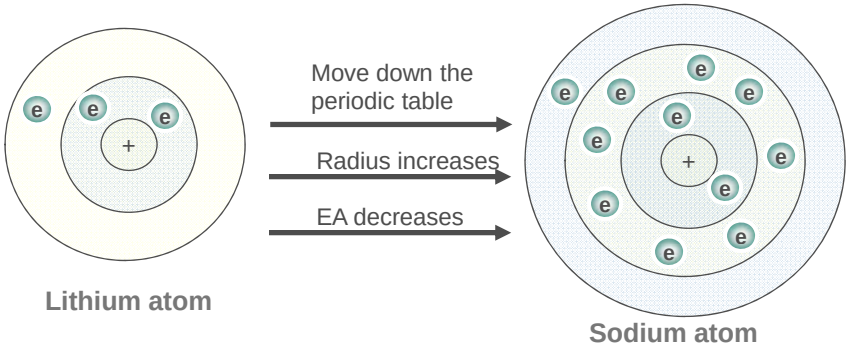
Electron Affinity Trends Reasoning - 2

Why does electron affinity decrease down a group?

As you move down a group, the radius increases as more electrons shells are added.



Lithium atom

Sodium atom

As the outer electrons (those involved in bonding) are farther from the nucleus, they will feel the "pull" of the nucleus less.

The larger atom is less able to "control" a new electron added.

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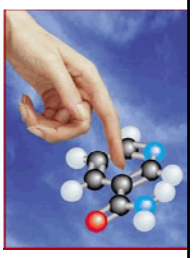
Ionic Charge & Radii



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Definition: Ion

Ion – Atom with a charge.

Cation – Positively charged ion. Results from loss of electrons.

Anion – Negatively charged ion. Results from gain of electrons.

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Predicting Ion Charge

Some ion charges can be determined from the element's placement on the periodic table.

Periodic Table - Charges of Common Ions

H^+																
Li^+	Be^{2+}												N^{3-}	O^{2-}	F^-	
Na^+	Mg^{2+}											Al^{3+}		P^{3-}	S^{2-}	Cl^-	
K^+	Ca^{2+}										Zn^{2+}	Ga^{3+}			Se^{2-}	Br^-	
Rb^+	Sr^{2+}									Ag^+	Cd^{2+}					I^-	
Cs^+	Ba^{2+}																
Fr^+	Ra^{2+}																

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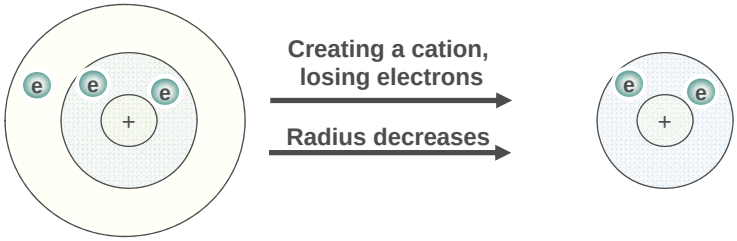
Ionic Radii - Cations

How does the radius of a cation compare to the parent atom?

Atoms lose electrons to create positive ions.



Lithium atom

Li^+ ion

When electrons are lost, there are now more protons than electrons.

Therefore, the protons have a greater "pull" on each of the electrons.

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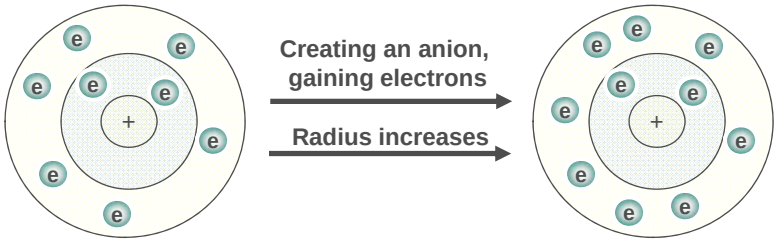
Ionic Radii - Anions

How does the radius of an anion compare to the parent atom?

Atoms gain electrons to create negative ions.



When electrons are gained, there are now more electrons than protons.

Therefore, the protons have a weaker "pull" on each of the electrons.

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Trend Summary and Examples

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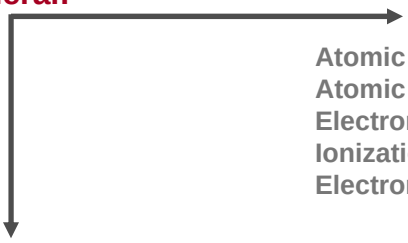
Summary of Trends

In general:



Atomic Mass: Increases
Atomic Radii: Decreases
Electronegativity: Increases
Ionization Energy: Increases
Electron Affinity: Increases

Atomic Mass: Increases
Atomic Radii: Increases
Electronegativity: Decreases
Ionization Energy: Decreases
Electron Affinity: Decreases

Don't memorize them all… understand the reasoning behind the atomic radii trend, and know the definitions of the other terms...then you can reason out their trends as well.

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Example #1

Example: **List Li, Cs and K in increasing order of:**

These elements are in the same group.

A: Atomic radii
Radii of the atom
As you move down a group, electron shells are added.
Li < K < Cs
This makes a larger atom.
The element at the top will be the smallest.

B: Electronegativity
Pull an atom has on electrons it shares in a bond.
As you move down a group, atoms get larger.
Cs < K < Li
The larger the atom, the less pull on the electrons.
Smallest atom will have the highest electronegativity.

C: Ionization Energy
Energy needed to remove the outermost electron.
As you move down a group, atoms get larger.
Cs < K < Li
The larger the atom, the less pull on the electrons.
Smallest atom will have the highest ionization energy.

D: Electron Affinity
Energy released when another electron is added.
As you move down a group, atoms get larger.
Cs < K < Li
The larger the atom, the less pull on the electrons.
Smallest atom will have the highest electron affinity.

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Example #2

Example: Put in order of increasing size: Ca, Ca^{2+} and Ca^{+}.

Cations are formed by removing electrons.
When electrons are removed, there are more protons per electron.
The pull on each electron from the nucleus is now greater.
The cation will be smaller than the parent atom.

$Ca^{2+} < Ca^{+} < Ca$

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Learning Summary

Other periodic trends (Electronegativity, Ionization Energy and Electron Affinity) can be reasoned through using the atomic radii trend.

The periodic table organizes the elements by atomic number.

Ions gain or lose electrons to form a charge. Cations are smaller and anions are larger than the "parent" atom.

The periodic table can be used to determine chemical properties of an element based on periodic trends.

Radii decreases across the periodic table and increases down the periodic table.

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Congratulations

You have successfully completed the tutorial

Periodic Table and Chemical Periodicity

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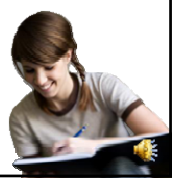
What's Next …

Step 1: Concepts – Core Tutorial (Just Completed)

→ **Step 2: Practice – Interactive Problem Drill**

Step 3: Recap – Super Review Cheat Sheet

Go for it!



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