Periodic Trends

objectives:

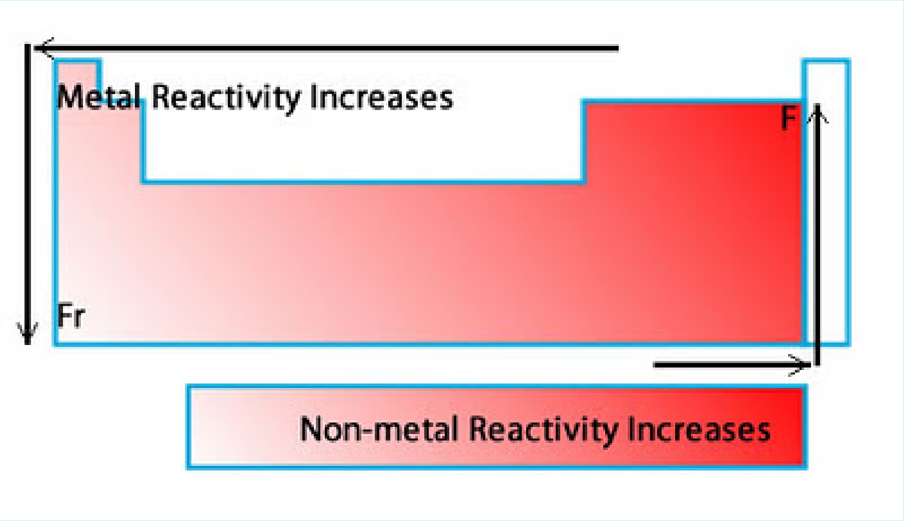
(#2-3) How do the properties of electrons and the electron shells contribute to the periodic trends?

1. (#2-3a) I can determine how gaining or losing **electrons** affects the atomic **radius** justified by **Coulomb's Law** and orbital structure.
2. (#2-3b) I can determine how gaining or losing **protons** affects the atomic **radius** justified by **Coulomb's Law** and orbital structure.
3. (#2-3c) I can determine how gaining or losing **electrons** affects the **ionization energy** justified by **Coulomb's Law** and orbital structure.
4. (#2-3d) I can determine how gaining or losing **protons** affects the **ionization energy** justified by **Coulomb's Law** and orbital structure.
5. (#2-3e) I can determine whether an atom is more or less **reactive** then another justified by **Coulomb's Law** and orbital structure.

Atomic Radius

Ionization Energy

Reactivity

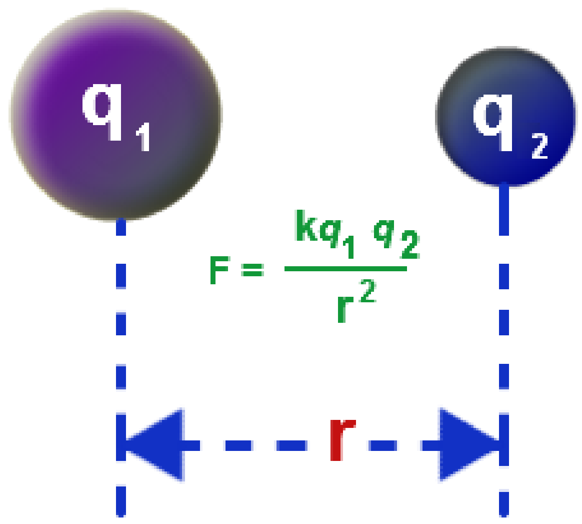


Oct 4-5:28 AM

Coulomb's Law

basis stability of atoms and ions
and periodic trends

2 variables: distance and charges



Coulomb’s law

Distance:
The closer two charges are, the stronger the force between them

Charge:
The greater the charges are, the stronger the force of attraction

F = Force

q = charge of a particle, need + and - to attract

r = radius (distance)

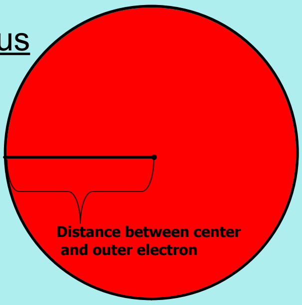
k = constant

protons/nucleus -- like a "beacon" sending out a positive charge to attract e^-

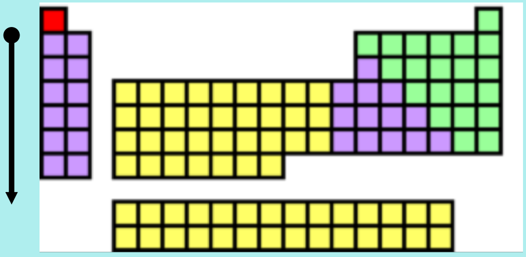
electron charge does not change

move closer or farther away depending on the amount of charge from the nucleus

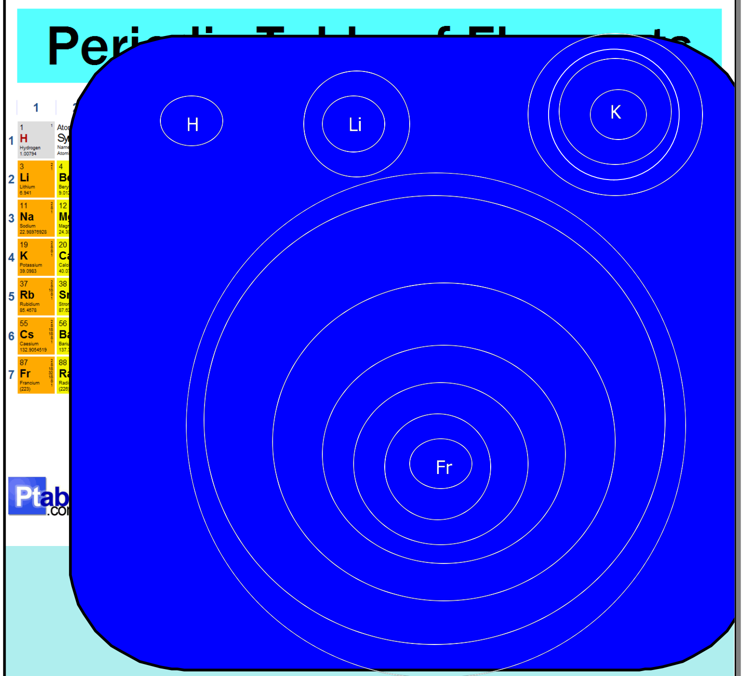
Atomic Radius



What do the radii of atoms compare as you move down the periodic table?



As you go down the PT, every row adds an energy level, so the radius will be bigger

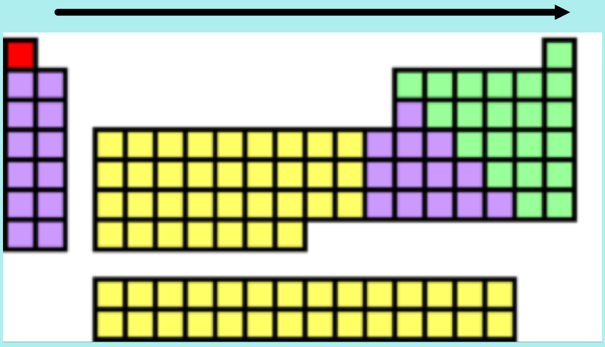


Which atom has largest radius? Why?

C(#6) Si(#14) Sn(#50)

Sn(#50), more energy levels or shells

What happens to the radius as you add electrons across the row?

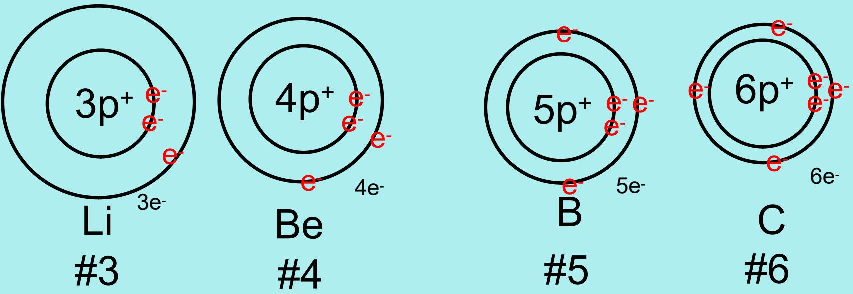


Across the PT - same valence shell, (left to right)

More p^+ --increase attraction (pulling) in same valence shell, so

the radii will decrease

Why? Coulomb's Law: p^+ charges increase, e^- have greater attraction (and held closer)



Which is bigger? Why?
S(#16) or Ar(#18)

S(#16) is bigger:
same valence shell,
more attraction
(Coulomb's Law) between
$18p^+$ and 18 e^-
than 16 p^+ and -16 e^-

Which atom is the biggest on the PT?

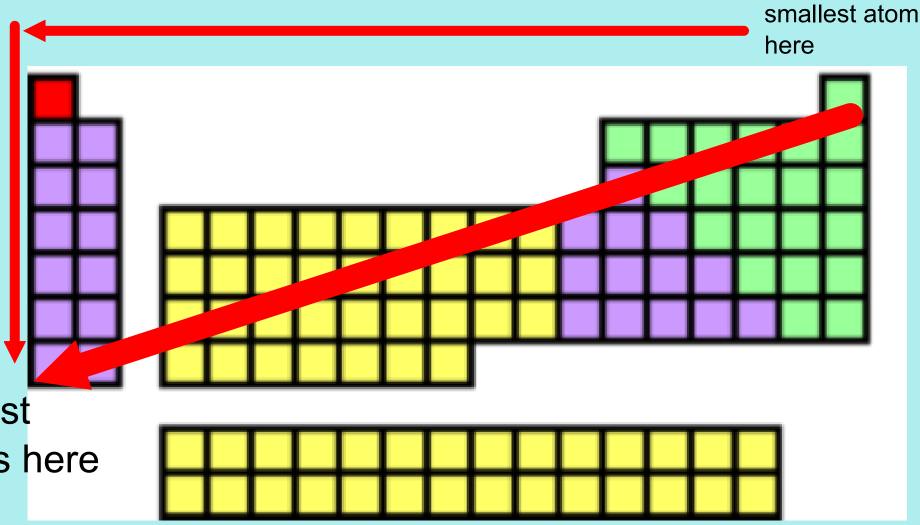
Fr(#87)
Coulomb's Law:
Distance: most valence shells
Charges: Fr has 87 protons compared to 118 protons on right side --Fr has least attraction in the 7th level

Oct 4-5:28 AM

Atomic Radii Trend:

increase as you go to the left

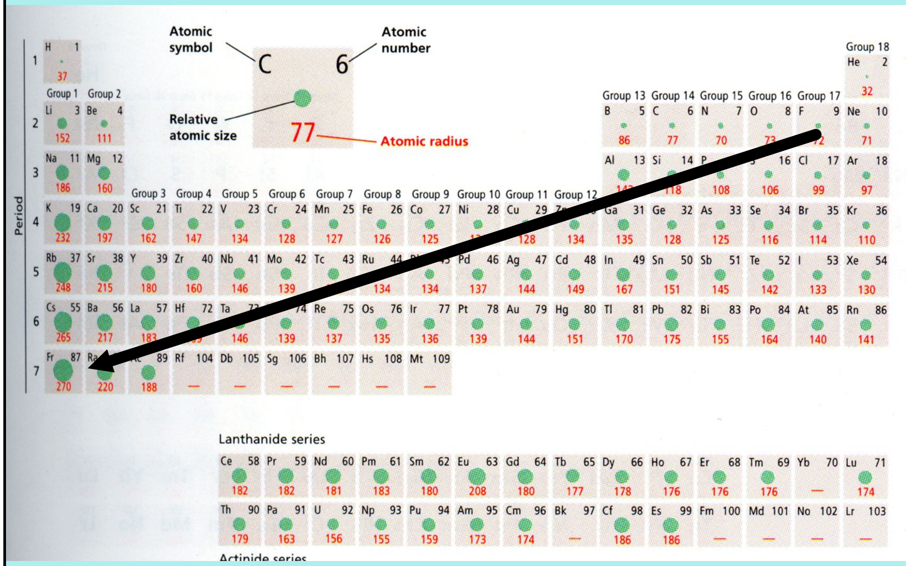
smallest atoms here



increase as you go down

biggest atoms here

Atomic Radii



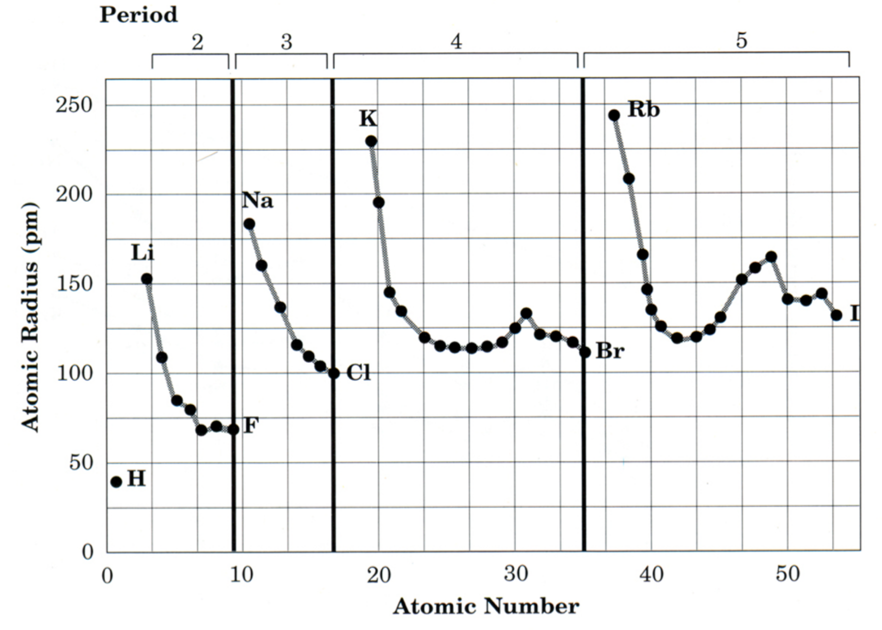
Period	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1	H 1 37																	He 2 32
2	Li 3 152	Be 4 111											B 5 86	C 6 77	N 7 70	O 8 73	F 9 72	Ne 10 71
3	Na 11 186	Mg 12 160											Al 13 [illegible]	Si 14 118	P 108	16 106	Cl 17 99	Ar 18 97
4	K 19 232	Ca 20 197	Sc 21 162	Ti 22 147	V 23 134	Cr 24 128	Mn 25 127	Fe 26 126	Co 27 125	Ni 28 [illegible]	Cu 29 128	Zn 134	Ga 31 135	Ge 32 128	As 33 125	Se 34 116	Br 35 114	Kr 36 110
5	Rb 37 248	Sr 38 215	Y 39 180	Zr 40 160	Nb 41 146	Mo 42 139	Tc 43 [illegible]	Ru 44 134	45 134	Pd 46 137	Ag 47 144	Cd 48 149	In 49 167	Sn 50 151	Sb 51 145	Te 52 142	I 53 133	Xe 54 130
6	Cs 55 265	Ba 56 217	La 57 183	Hf 72 [illegible]	Ta 73 146	74 139	Re 75 137	Os 76 135	Ir 77 136	Pt 78 139	Au 79 144	Hg 80 151	Tl 81 170	Pb 82 175	Bi 83 155	Po 84 164	At 85 140	Rn 86 141
7	Fr 87 270	Ra 220	Ac 89 188	Rf 104 —	Db 105 —	Sg 106 —	Bh 107 —	Hs 108 —	Mt 109 —									

Lanthanide series

Ce 58 182	Pr 59 182	Nd 60 181	Pm 61 183	Sm 62 180	Eu 63 208	Gd 64 180	Tb 65 177	Dy 66 178	Ho 67 176	Er 68 176	Tm 69 176	Yb 70 —	Lu 71 174
Th 90 179	Pa 91 163	U 92 156	Np 93 155	Pu 94 159	Am 95 173	Cm 96 174	Bk 97 —	Cf 98 186	Es 99 186	Fm 100 —	Md 101 —	No 102 —	Lr 103 —

Actinide series

Graph --shows trends



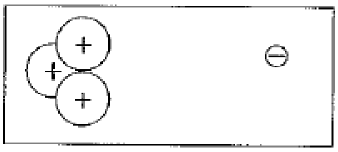
Why does the radius increase from H, to Li, to Na, to K to Rb?

These are all Alkali Metal family atoms, and each new row is a new energy level, (each new shell (energy level increases the radius)

Why does the graph decrease after each alkali metal?

Protons are increasing as you go across the period, increasing effective nuclear charge which gives greater attraction ("hug" in closer) and decreased radius of the atom

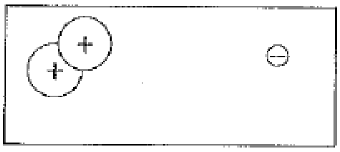
1. Rank the following sets of particles in order of INCREASING force of attraction on the electron.


Set A


Set B


Set C

2. Rank the following sets of particles in order of INCREASING force of attraction on the electron.


Set A


Set B


Set C

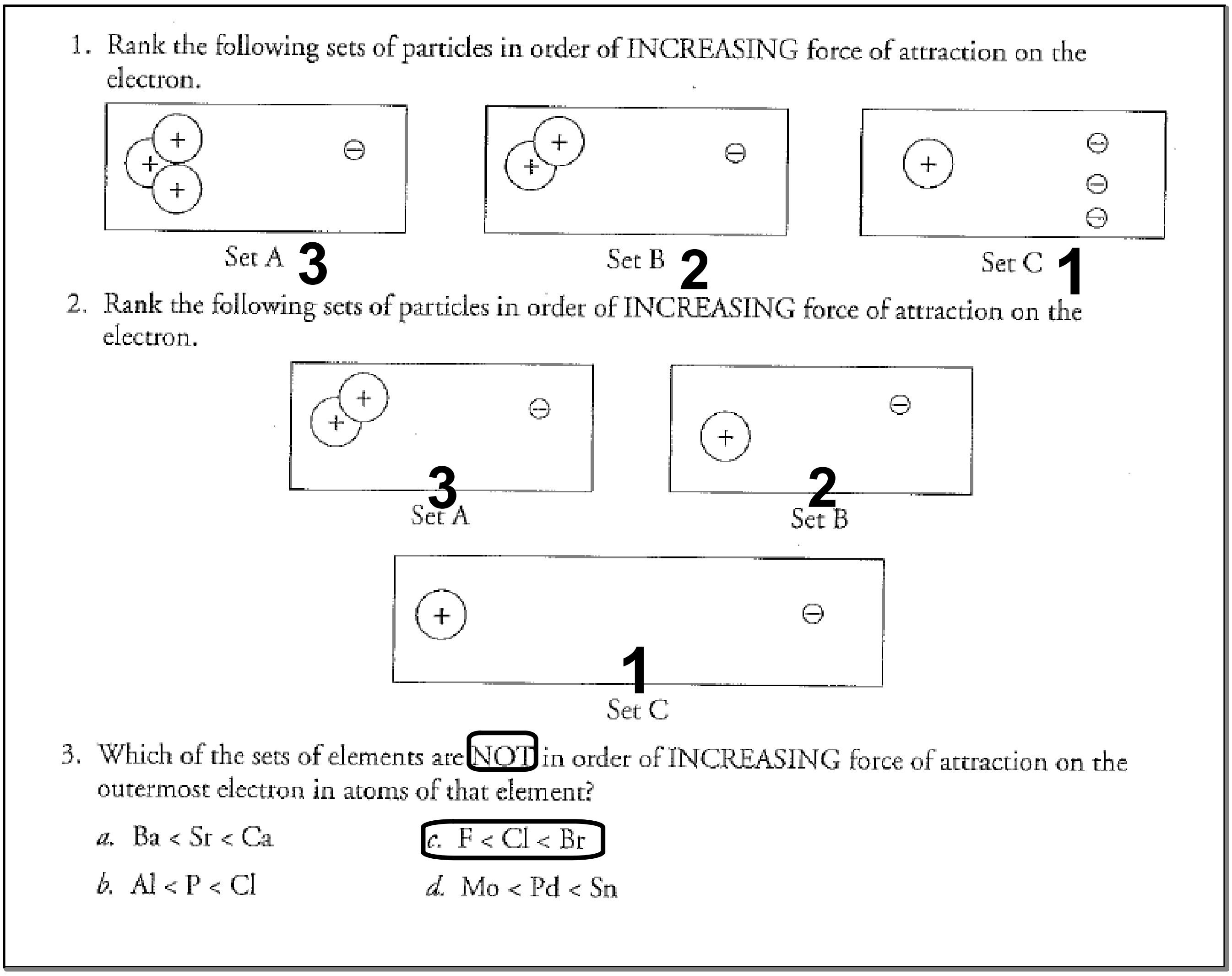
3. Which of the sets of elements are NOT in order of INCREASING force of attraction on the outermost electron in atoms of that element?

a. Ba < Sr < Ca

b. Al < P < Cl

c. F < Cl < Br

d. Mo < Pd < Sn



1. Rank the following sets of particles in order of INCREASING force of attraction on the electron.

Set A 3

Set B 2

Set C 1

2. Rank the following sets of particles in order of INCREASING force of attraction on the electron.

3 Set A

2 Set B

1 Set C

3. Which of the sets of elements are NOT in order of INCREASING force of attraction on the outermost electron in atoms of that element?

a. Ba < Sr < Ca

[✓ *c.* F < Cl < Br]

b. Al < P < Cl

d. Mo < Pd < Sn

Reactivity

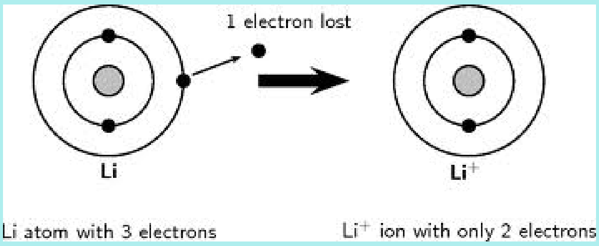
atom is reactive

valence shell not full

e^- are easily gained or lost

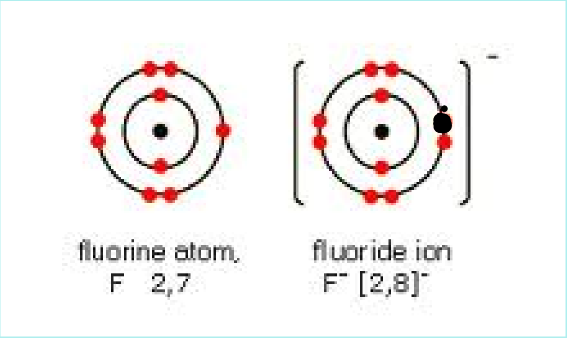
Metals like to lose electrons.

$Li \longrightarrow Li^+$



Non-metals like to gain electrons

$F \longrightarrow F^-$



atom is not reactive

Full valence shell=stability

lowest energy state

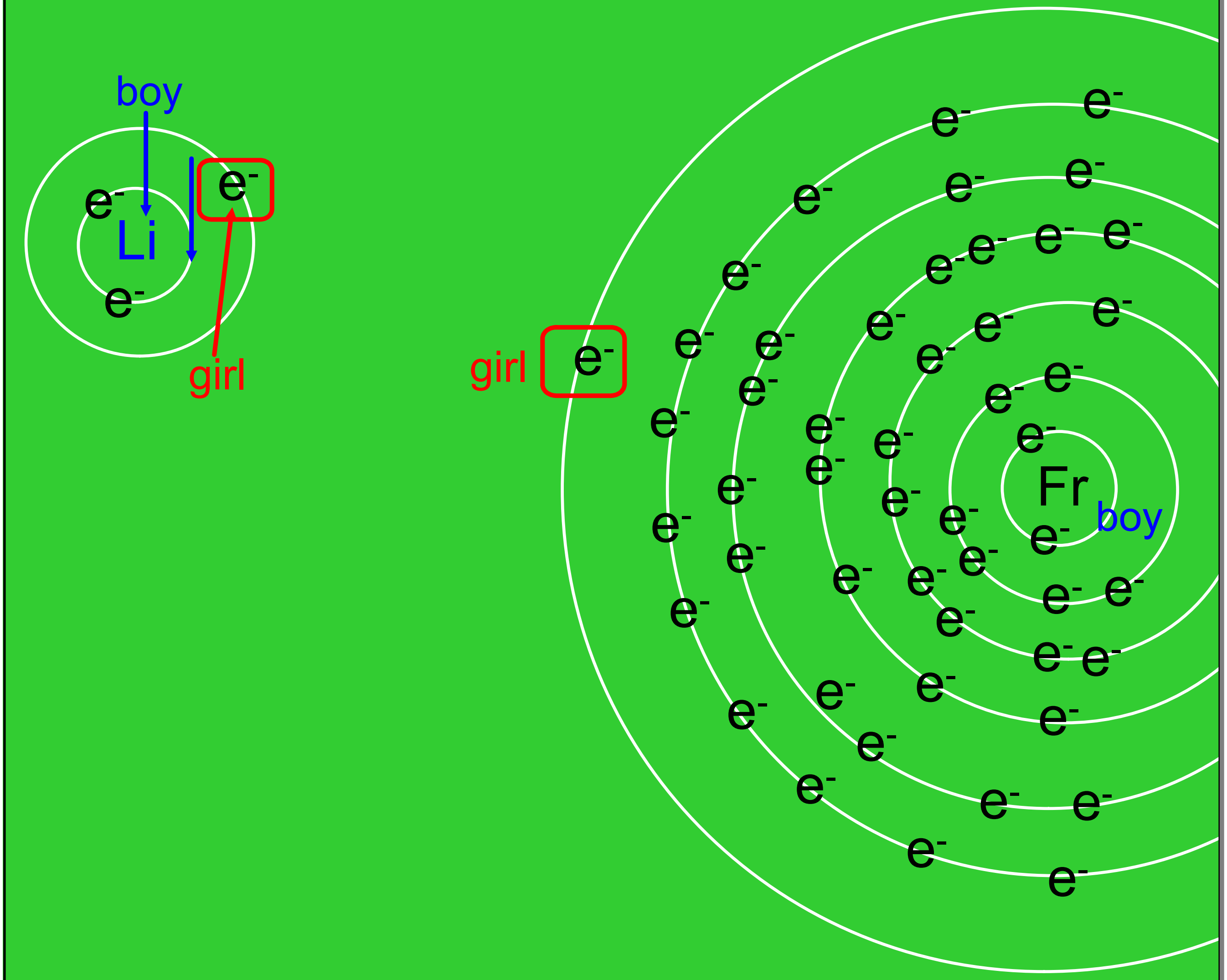
I'm full!

noble gases

Highest charge at that energy level

Metal reactivity analogy

*Proximity (distant e⁻ --more reactive)

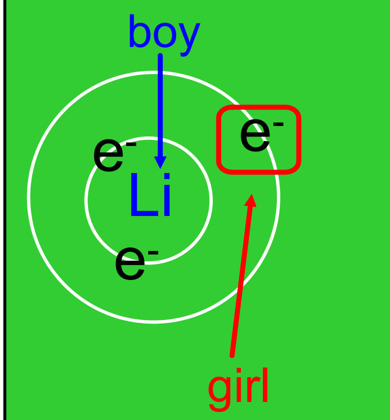


Metal reactivity analogy

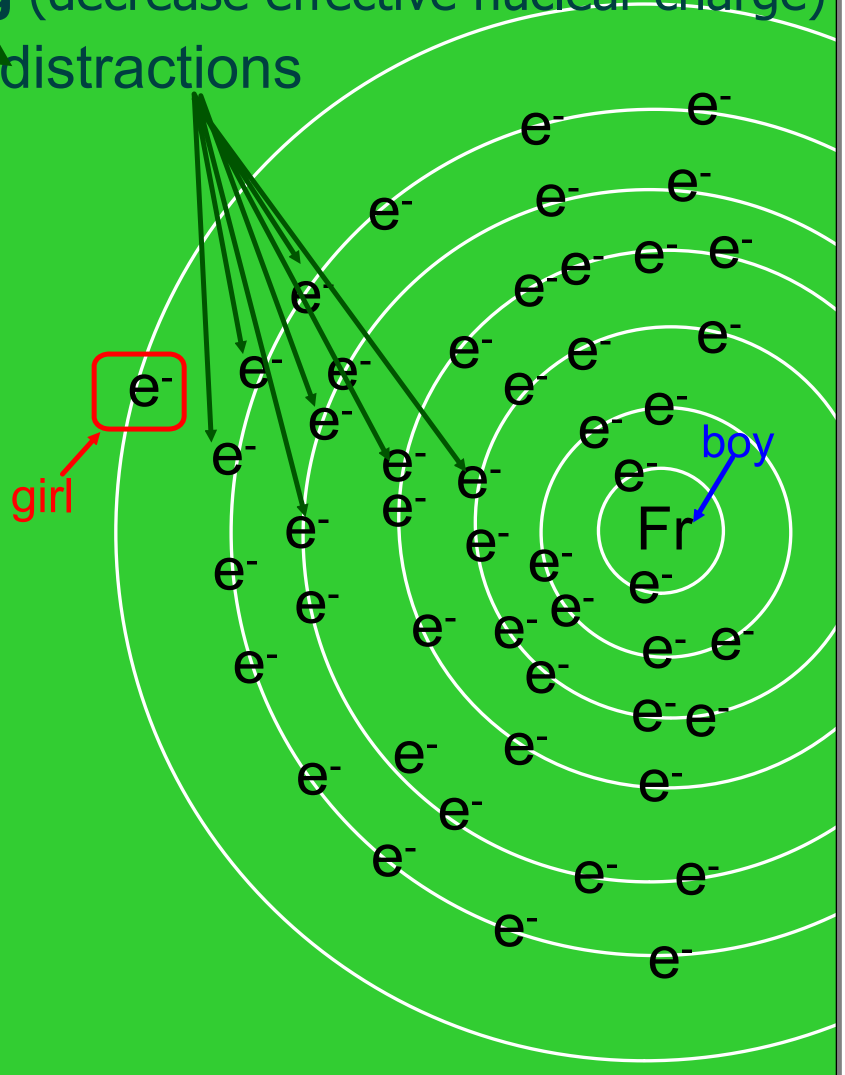
*Proximity (distant e$^-$ --more reactive)

***Shielding** (decrease effective nuclear charge)

distractions



this e$^-$ is close to the nucleus and has a stronger attraction and no "distractions"



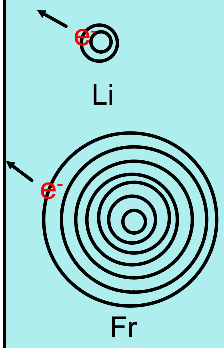
difference between metals and non-metals

lose e^- **gain e^-**

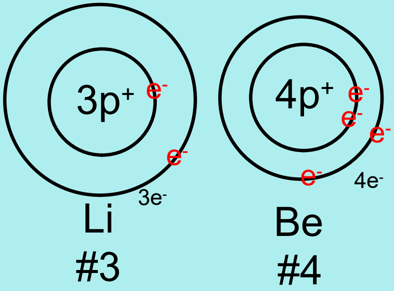
Reactivity of **metals**

Metals --- lose electrons.

Therefore, the farther away the e^- is, the easier it is to lose and the more reactive it is



Alkali Metals (Gp1) Vs. Akaline Earth Metals (Gp2)

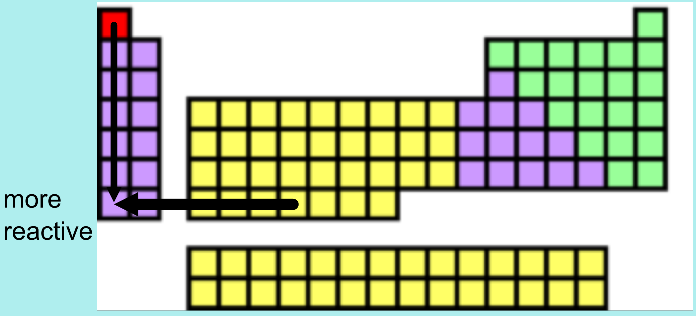


Li (Gp 1) is more reactive than Be (Gp 2)

-Li e^- is less attracted to nucleus than Be

-easier (less energy) to lose 1 e^- on Li

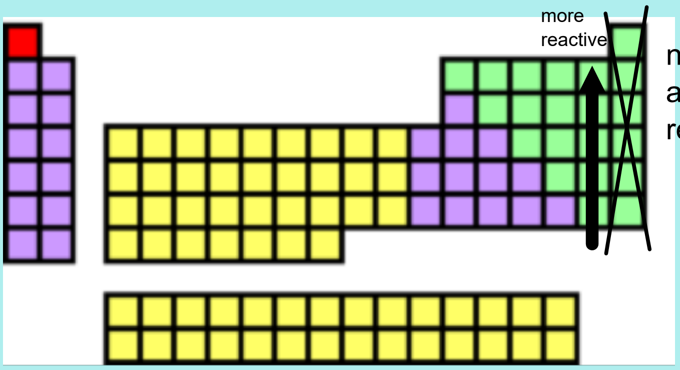
-Coulomb's Law -- Distance and Charge



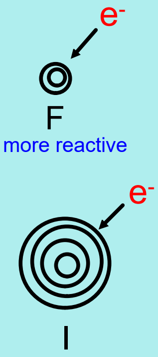
Reactivity of **Non-metals**

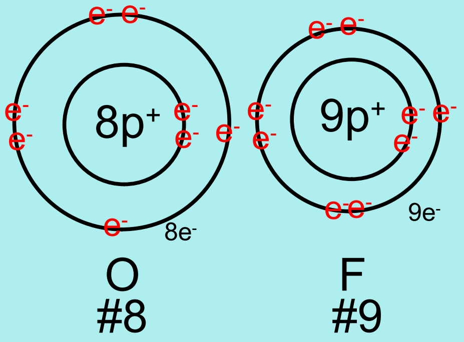
Non-metals --- gain e^-.

Therefore, the closer the e^- is,
the easier it is to gain
and the more reactive it is.

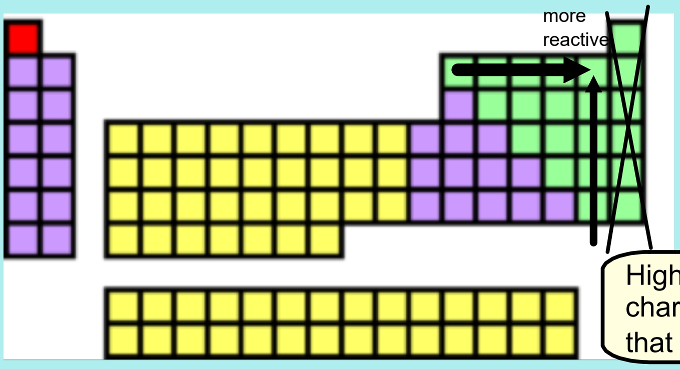


noble gases
are not
reactive





F is more reactive than O
-e^- is more attracted to F nucleus
with 9 protons
-easier (less energy) to gain 1 e^- on F
-Coulomb's Law --more Charge on F

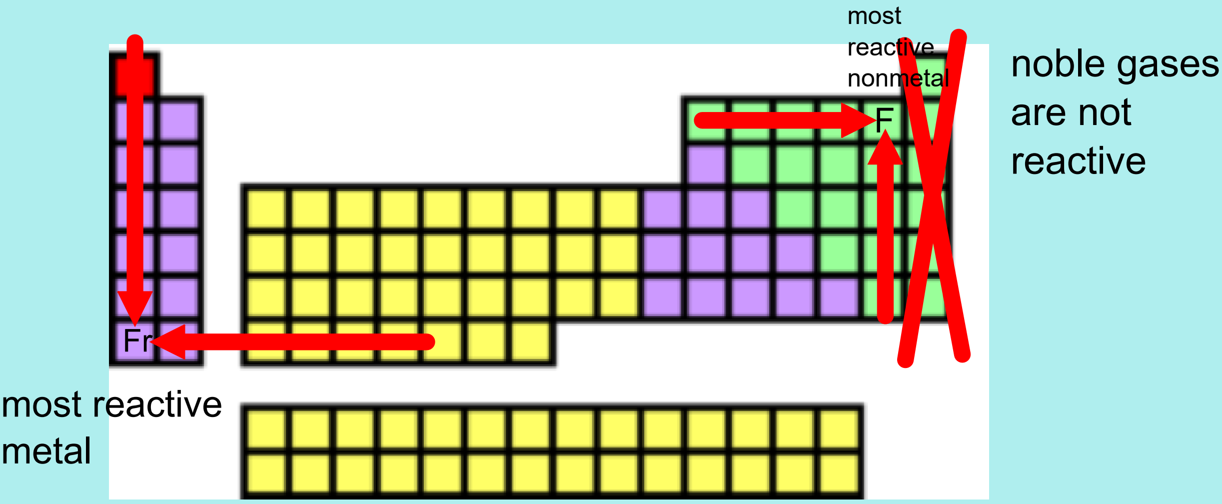


noble gases
are not
reactive

Highest nuclear
charge at
that energy level

Reactivity

Summary

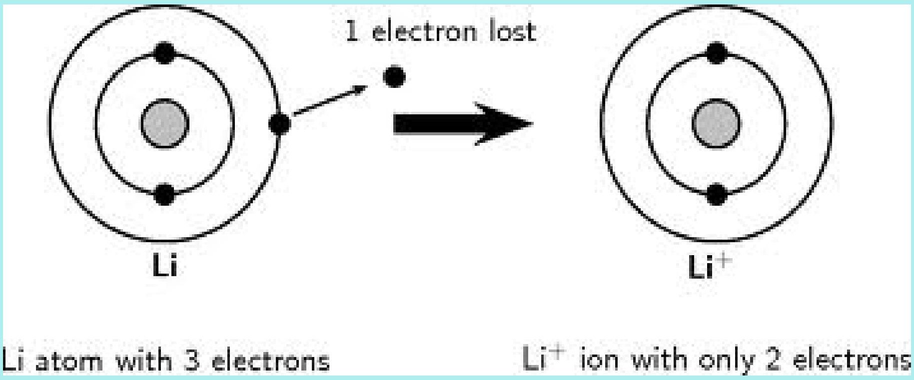


noble gases are not reactive

most reactive metal

Ionization Energy

Amount of energy needed to remove an e^-.



-Amount of energy needed to remove succeeding e^- always requires more energy.

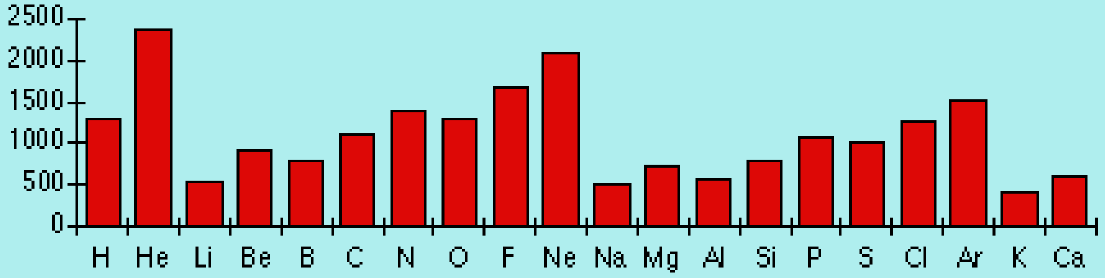
-Pulling a negative away from a positive is more difficult. (requires more energy)

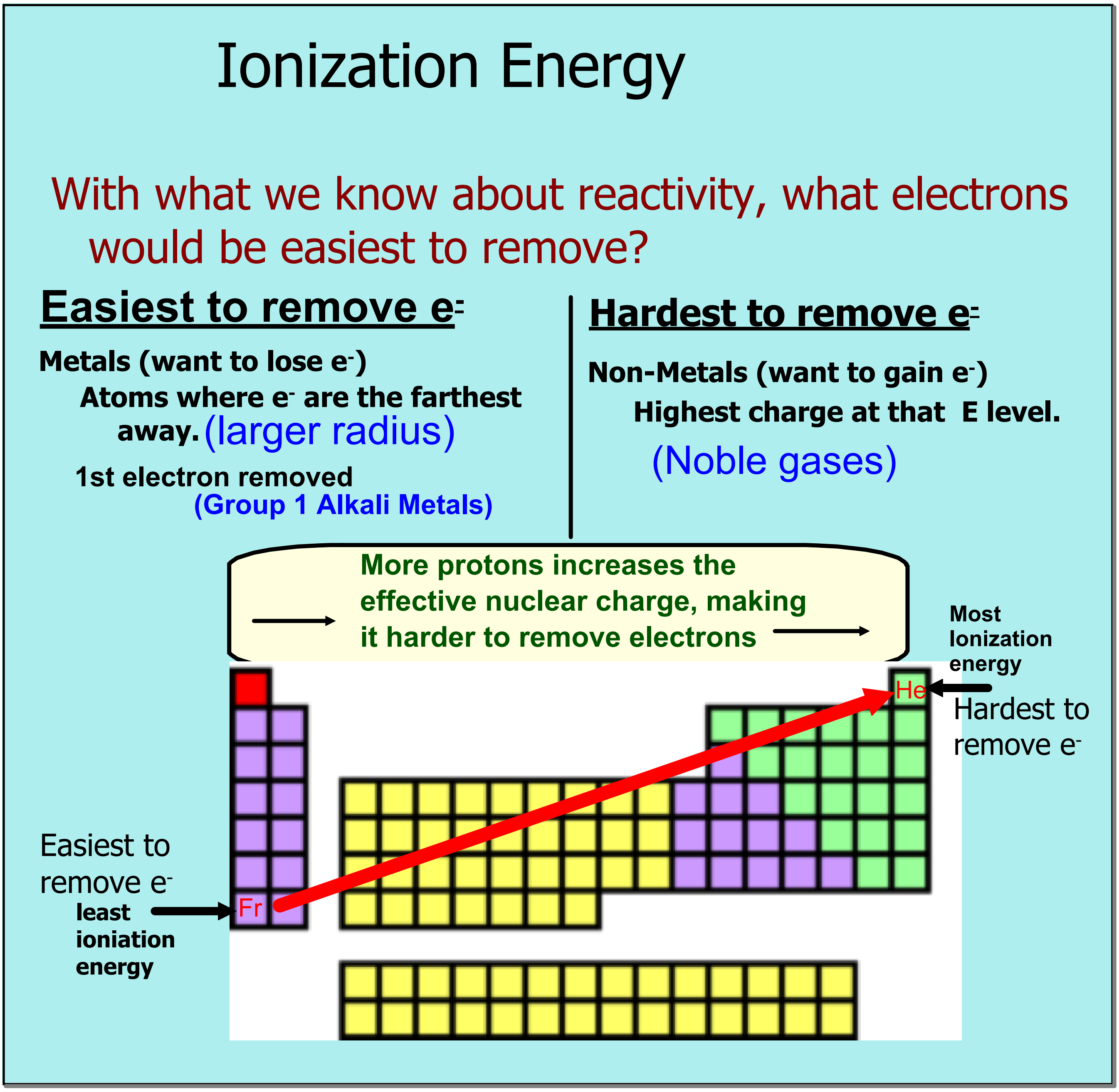
Which family on the PT needs the most energy to remove e^- (highest ionization energy?)

noble gases

Which family on the PT requires the least energy to remove e^- (lowest ionization energy?)

Alkali Metals


First ionisation energies from hydrogen to calcium (kJ per mole)



Ionization Energy

With what we know about reactivity, what electrons would be easiest to remove?

Easiest to remove e^-

Metals (want to lose e^-)

Atoms where e^- are the farthest away. (larger radius)

1st electron removed

(Group 1 Alkali Metals)

Hardest to remove e^-

Non-Metals (want to gain e^-)

Highest charge at that E level.

(Noble gases)

More protons increases the effective nuclear charge, making it harder to remove electrons

Most Ionization energy

Hardest to remove e^-

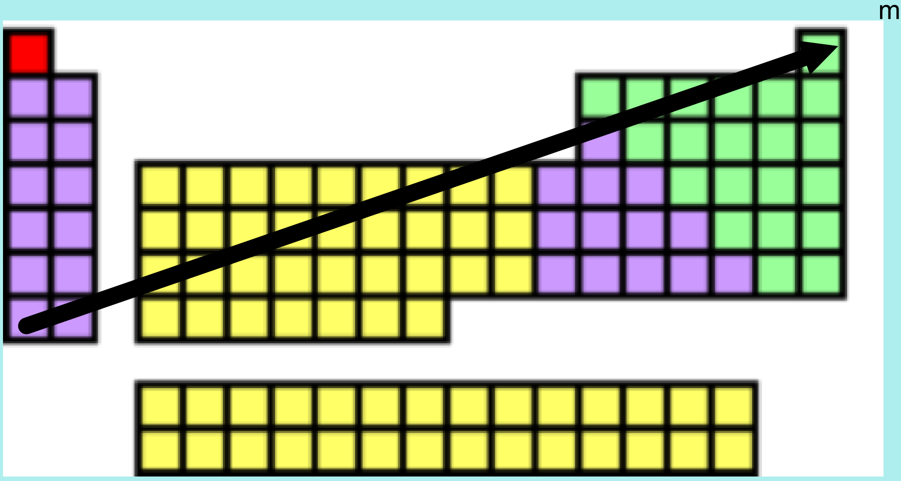
Easiest to remove e^-

least ioniation energy

Ionization energy

summary

What is the trend?



most IE

least IE

Oct 5-2:36 PM

Coulombs Law

$$F = \frac{k(q^{+} \cdot q^{-})}{d^{2}}$$

Explanations:

1. Coulombic Attraction: **Distance**
   Difference in energy level
2. Coulombic Attraction: **Charge**
   Difference in nuclear charge
3. Electrons Repelling

Compare and explain:

Larger radius? Why

a. Mg (#12) or Cl (#17)

b. Mg(#12) or Ra (#88)

c. Na or Na^{+1}

d. O or O^{-2}

Smaller ionization energy? Why?

a. K(#19) or Ca (20)

b. Mg (#12) or Cl (#17)

c. Mg(#12) or Ra (#88)

Oct 12-8:58 AM

Coulombs Law

$$F = \frac{k(q^+ \cdot q^-)}{d^2}$$

Explanations:

1. Coulombic Attraction: **Distance**
   Difference in energy level
2. Coulombic Attraction: **Charge**
   Difference in nuclear charge
3. Electrons Repelling

Compare and explain:

Larger radius? Why

a. Mg (#12) or Cl (#17)

12 p+ 17 p+

greater attraction

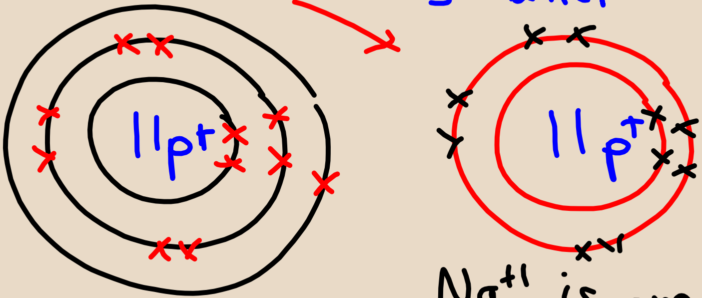
② Because of Coulombic attraction, the charge. is greater Cl is smaller

b. Mg(#12) or Ra (#88)

↑ 3 energy levels 7 energy levels

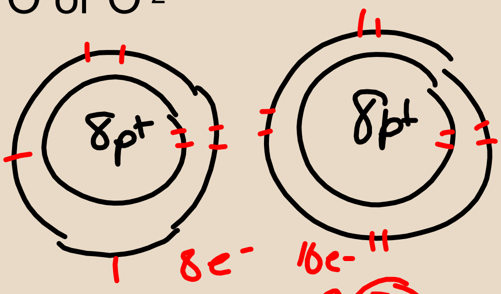
① Due due C.L. greater distance for Ra, Ra is larger

c. Na or Na^{+1}



Na^{+1} is smaller

d. O or O^{-2}

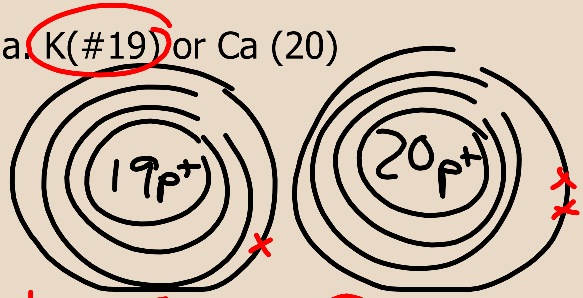


↑③

more e- repel + O^{-2} is larger

Smaller ionization energy? Why?

a. K(#19) or Ca (20)



less E smaller IE,

② C.L. greater effective nuclear charge more E to remove e-

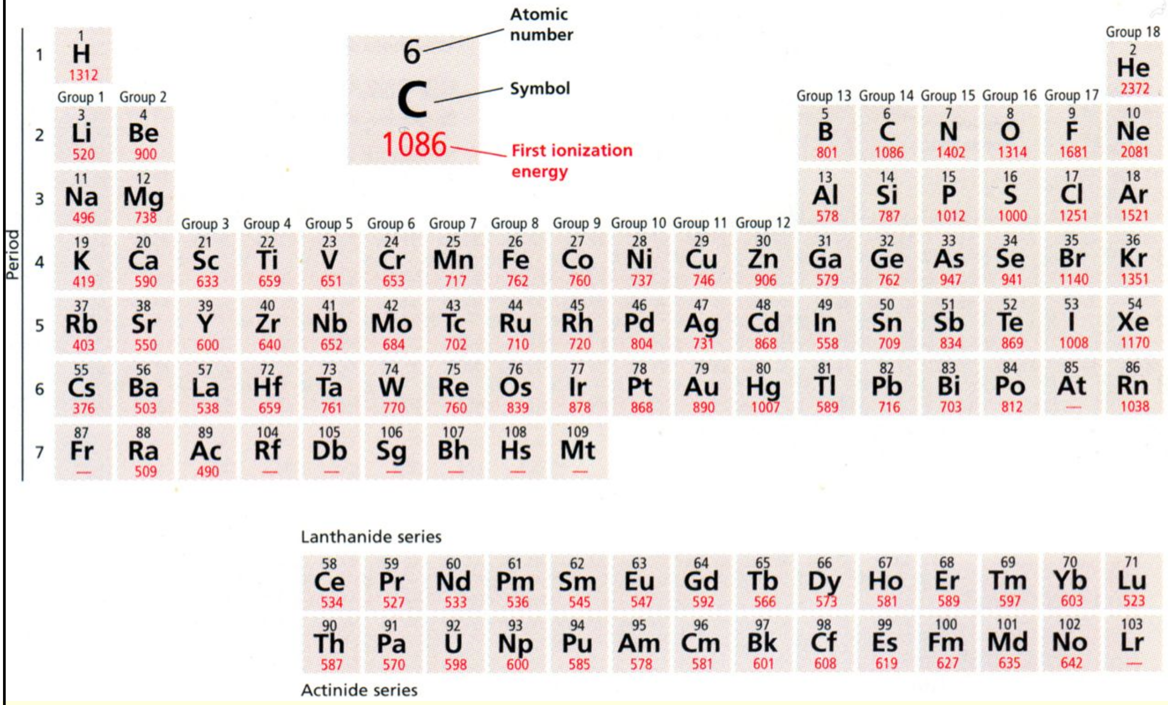
b. Mg (#12) or Cl (#17)

12p+ 17p+

smaller IE ②

c. Mg(#12) or Ra (#88)

First Ionization Energy

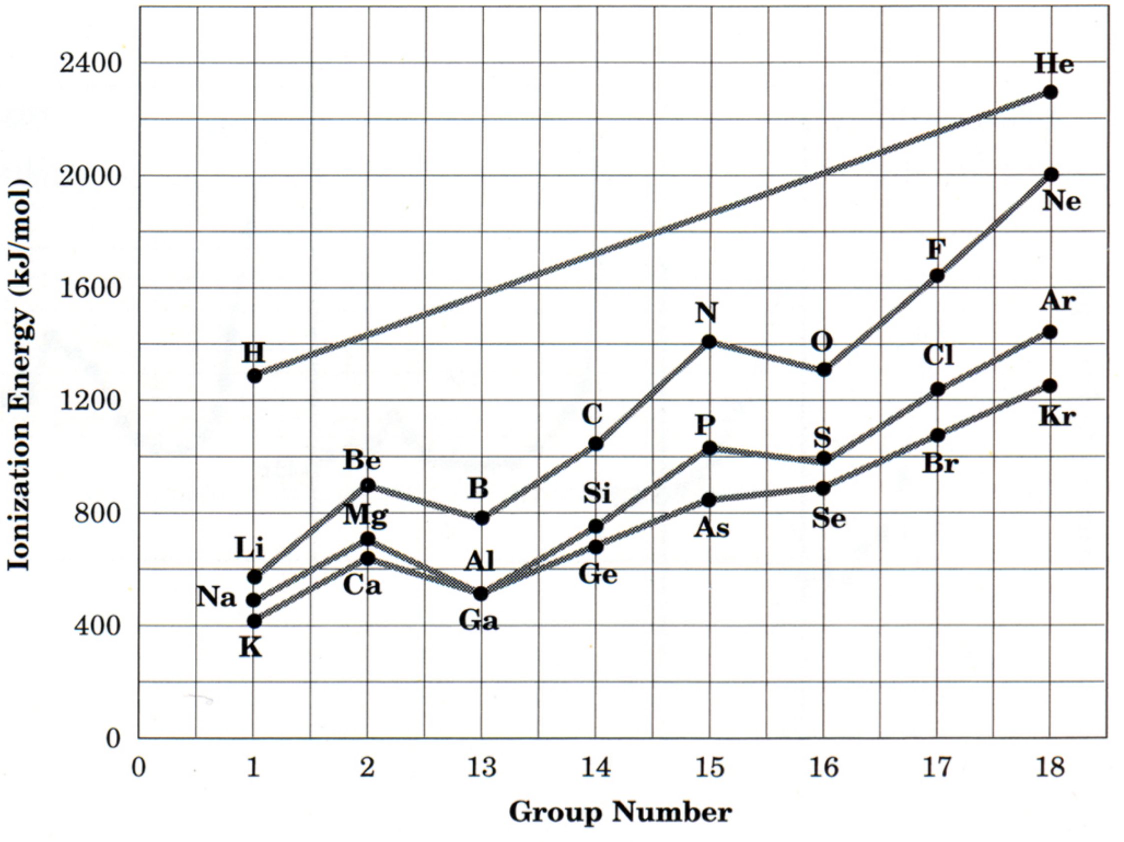


6 — Atomic number
C — Symbol
1086 — First ionization energy

Period	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1	1 H 1312																	2 He 2372
2	3 Li 520	4 Be 900											5 B 801	6 C 1086	7 N 1402	8 O 1314	9 F 1681	10 Ne 2081
3	11 Na 496	12 Mg 738											13 Al 578	14 Si 787	15 P 1012	16 S 1000	17 Cl 1251	18 Ar 1521
4	19 K 419	20 Ca 590	21 Sc 633	22 Ti 659	23 V 651	24 Cr 653	25 Mn 717	26 Fe 762	27 Co 760	28 Ni 737	29 Cu 746	30 Zn 906	31 Ga 579	32 Ge 762	33 As 947	34 Se 941	35 Br 1140	36 Kr 1351
5	37 Rb 403	38 Sr 550	39 Y 600	40 Zr 640	41 Nb 652	42 Mo 684	43 Tc 702	44 Ru 710	45 Rh 720	46 Pd 804	47 Ag 731	48 Cd 868	49 In 558	50 Sn 709	51 Sb 834	52 Te 869	53 I 1008	54 Xe 1170
6	55 Cs 376	56 Ba 503	57 La 538	72 Hf 659	73 Ta 761	74 W 770	75 Re 760	76 Os 839	77 Ir 878	78 Pt 868	79 Au 890	80 Hg 1007	81 Tl 589	82 Pb 716	83 Bi 703	84 Po 812	85 At —	86 Rn 1038
7	87 Fr —	88 Ra 509	89 Ac 490	104 Rf —	105 Db —	106 Sg —	107 Bh —	108 Hs —	109 Mt —									

Lanthanide series	58 Ce 534	59 Pr 527	60 Nd 533	61 Pm 536	62 Sm 545	63 Eu 547	64 Gd 592	65 Tb 566	66 Dy 573	67 Ho 581	68 Er 589	69 Tm 597	70 Yb 603	71 Lu 523
Actinide series	90 Th 587	91 Pa 570	92 U 598	93 Np 600	94 Pu 585	95 Am 578	96 Cm 581	97 Bk 601	98 Cf 608	99 Es 619	100 Fm 627	101 Md 635	102 No 642	103 Lr —

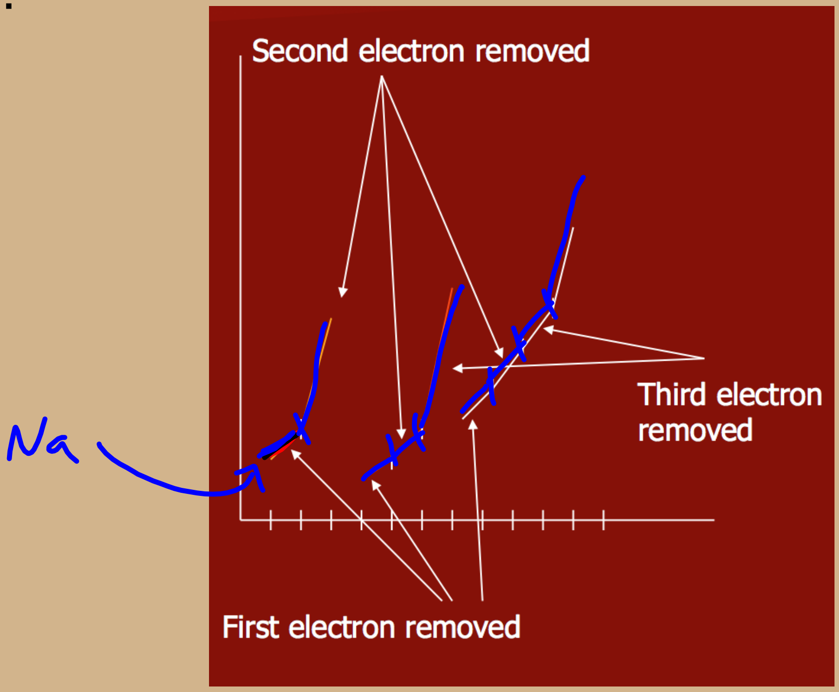
Graph



Removing succeeding electrons

First electrons are always the easiest electrons to remove.

Why did the ionization energy spike at different times?

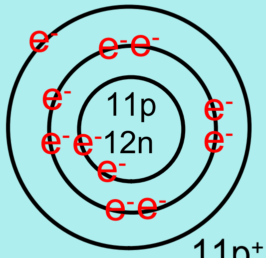


Na: 1 Valence electron Na^+
Mg: 2 Valence electrons Mg^{+2}
Al: 3 Valence electrons Al^{+3}

After clearing out a shell it is very difficult to break into a full shell.

Ionic Radii

What happens to the radius if electrons are lost?
Metal cations lose whole shell

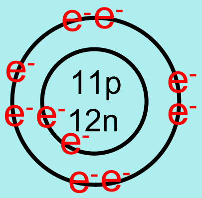


Na atom

$11p^+$
$11e^-$

3 shells, larger

→
lose
1 e^-



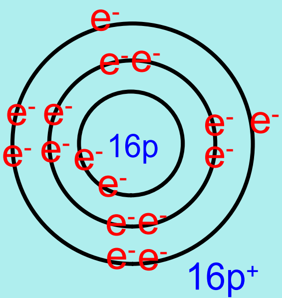
Na^{+1}

$11p^+$
$10e^-$

2 shells, smaller

What happens to the radius if electrons are gained?

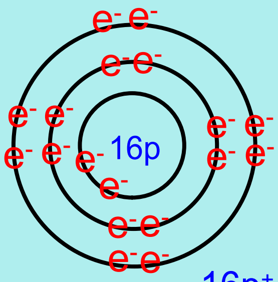
Nonmetal Anions - gain electrons.



$16p^+$
$16e^-$

S
atom

→
gain
2 e^-

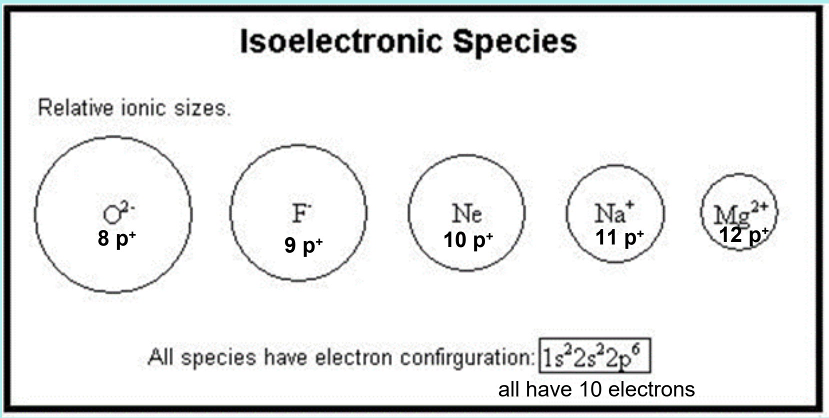


S^{-2}
ion

$16p^+$
$18e^-$

Proton "beacon" is the same force of attraction
Extra electrons will repel each other, slightly increasing the radius

Isoelectronic Comparison of ion radii:



All species have electron confirguration: $1s^22s^22p^6$
all have 10 electrons

the charge increase, therefore the Coulomic Force increases,
electrons are closer and the radius is smaller

Sample questions for quiz:

1. 2 factors of Coulomb’s law?

2. Which element has a bigger radius? Explain with Coulomb's Law.

   a. Li or B?

   b.O or S?

3. What is ionization energy?

4. What determines ionization energy?

5.Which element has lower Ionization Energy?Explain with Coulomb's Law.

   a. Li or B?

   b.O or S?

6. Which electron is harder to remove, the 1st e or the 2nd electron?

7. Why does Cesium have a low ionization energy compared to Li?

8. Why does Neon have a high ionization energy compared to C?

Sample questions for quiz:

1. 2 factors of Coulomb's law?

2. Which element has a bigger radius? Explain with Coulomb's Law.

a. Li or B? 3p+ 5p+ greater charge

b. O or S? O S 8p 16p+ more E levels

3. What is ionization energy?

4. What determines ionization energy? C.L.

5. Which element has lower IE? Explain with Coulomb's Law.

a. Li or B? ② charge

b. O or S? 2 3 levels - distance easier pull off e-

6. Which electron is harder to remove, the 1st e or the 2nd electron?

1st is easiest

$$Al \rightarrow Al^{+1} \rightarrow Al^{+2} \rightarrow Al^{+3}$$

e- e- e-

harder to pull a e- (neg) from a positive

7. Why does Cesium have a low ionization energy compared to Li?

2 Li

6 Cs

Cs has more E levels than Li Due to C.L., greater distance has less attraction ∴ easier to pull off e-

8. Why does Neon have a high ionization energy compared to C?

C #6 Ne #10

C has less attraction due to eff. nuclear charge · easier to pull off e-