



CHEM 1101B- Chemistry for Engineers

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HS (Health Sciences) 1301

Mondays & Wednesdays 8:35am - 9:55am

Lecture 4: Periodicity

Please feel free to
introduce yourself to your
neighbors– name,
pronouns, a hobby, etc.

and/or

Answer the first question
on Wooclap!

Learning outcomes Topic 4:

The ATOM – Periodicity

- Relate chemical and physical properties to electron configurations
- Predict relative atomic radius, ionization energies and electronegativities

Explaining the Periodic Table

Recall: valence electrons are electrons in the outermost shell (outermost principle quantum number) of an atom

- Elements in the same group have the same valence electron configuration
- Elements with the same valence electron configuration show similar chemical behaviour
- Electron configurations can be used to explain periodic trends

i.e.

Why is the **atomic radius** of potassium larger than that of sodium?

Why is the **first ionization energy** higher in beryllium than in lithium?

H 1s ¹									He 1s ²		
Li 2s ¹	Be 2s ²					B 2p ¹	C 2p ²	N 2p ³	O 2p ⁴	F 2p ⁵	Ne 2p ⁶
Na 3s ¹	Mg 3s ²					Al 3p ¹	Si 3p ²	P 3p ³	S 3p ⁴	Cl 3p ⁵	Ar 3p ⁶

Figure 8 The valence electron configurations for the first 18 elements

Underlying Patterns of Periodicity

n 1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

Periodicity: Regular changes of physical properties across a period or down a group.

Z increases while n is fixed
Consequences: Orbitals shrink
Stability increases

n increases while Z_{eff} increases slowly
Consequences: Orbitals expand
Stability decreases

Recap: Underlying Patterns of Periodicity

Patterns are dependent on the:

- (1) principal quantum number, n
- (2) atomic number, Z

Across a row in the periodic table (left to right)

- n (number of shells) stays the same, Z increases
- Positive charge in the nucleus (nuclear charge) increases, pulling the outer valence electrons closer to the nucleus (stronger attraction), reducing the atom's size
- Electrons closer to the nucleus are energetically more stable

Down a column the periodic table

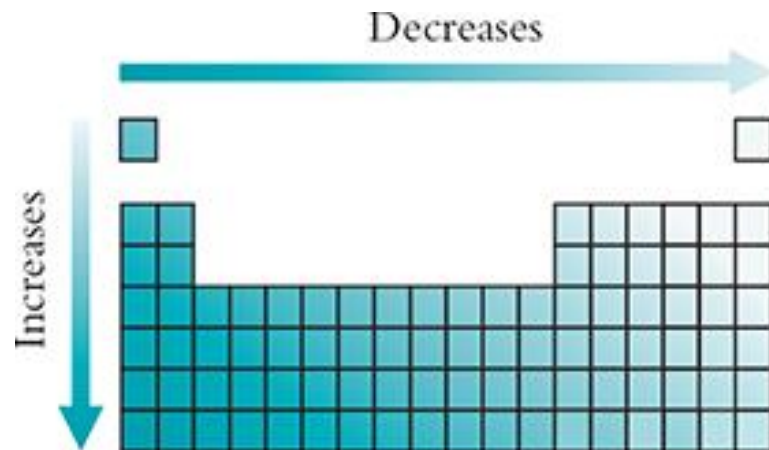
- n (number of shells) and Z both increase, however, n is the dominating factor for determining orbital size and stability within a column
- The atom is continuously becoming bigger as the valence electrons occupy a level that is farther from the nucleus
- Valence orbitals get larger and less stable

General Trend #1: Atomic Radius/Size

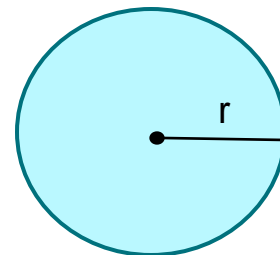
Atomic radius: The distance from the nucleus to the approximate outer boundary of electrons

What dictates atomic radius/size?

- **Outer valence electrons**
- Moving **down** a group, the atomic radius \uparrow
 - As $n \uparrow$, atomic/valence orbitals become **larger** and less stable
- **Across** a period (left to right), the atomic radius \downarrow
 - As $Z \uparrow$, atomic orbitals become **smaller** and more stable



Atomic radii



Atomic Radii/Size: Valence Electrons

		Z	n _{e- core}	n _{e- valance}
₃ Li:	1s ² , 2s ¹	3	2	1
₄ Be:	1s ² , 2s ²	4	2	2
₅ B:	1s ² , 2s ² , 2p ¹	5	2	3
₆ C:	1s ² , 2s ² , 2p ²	6	2	4
₇ N:	1s ² , 2s ² , 2p ³	7	2	5
₈ O:	1s ² , 2s ² , 2p ⁴	8	2	6
₉ F:	1s ² , 2s ² , 2p ⁵	9	2	7
₁₀ Ne:	1s ² , 2s ² , 2p ⁶	10	2	8
₁₁ Na:	1s ² , 2s ² , 2p ⁶ , 3s ¹	11	10	1

Example: Trends in Atomic Radii/Size

wooclap



For each of the following, rank in order of increasing atomic size (smallest to biggest)

a) Mg, Si, S

b) As, N, P

1 1A H																	18 8A He																					
1 H Hydrogen 1.008	2 2A He Helium 4.003																	2																				
3 Li Lithium 6.941	4 Be Beryllium 9.012																																					
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 B Boron 10.811	14 C Carbon 12.011	15 N Nitrogen 14.007	16 O Oxygen 15.999	17 F Fluorine 18.998	18 Ne Neon 20.180																															
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798																					
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294																					
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)																					
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinide Series	104 Pa Protactinium 231.036	105 U Uranium 238.029	106 Np Neptunium 237.048	107 Pu Plutonium 244.064	108 Am Americium 243.061	109 Cm Curium 247.07	110 Bk Berkelium 247.07	111 Cf Californium 251.083	112 Es Einsteinium (252)	113 Fm Fermium (257)	114 Md Mendelevium (258)	115 No Nobelium (259)	116 Lr Lawrencium (262)	117 Ts Tennessine (294)	118 Og Oganesson (294)																					
																			57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.502	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967					
																			89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.07	97 Bk Berkelium 247.07	98 Cf Californium 251.083	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)					

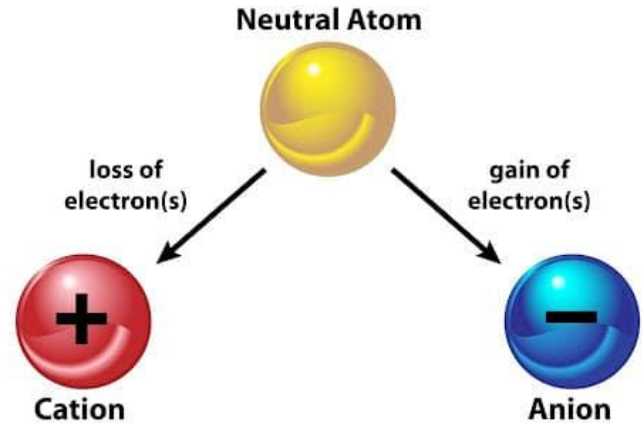
What to do when both rules apply?

Arrange the following atoms in order of increasing size (smallest to biggest): **Al**, **C**, **S**

Periodic Table of the Elements																																			
1 1A 1A		2 2A 2A																18 8A 8A																	
1 H Hydrogen 1.008																																			
3 Li Lithium 6.941		4 Be Beryllium 9.012																																	
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87 Fr Francium 223		88 Ra Radium 226		89-103 Actinide Series		104 Rf Rutherfordium (261)		105 Db Dubnium (262)		106 Sg Seaborgium (266)		107 Bh Bohrium (264)		108 Hs Hassium (277)		109 Mt Meitnerium (268)		110 Ds Darmstadtium (271)		111 Rg Roentgenium (272)		112 Cn Copernicium (285)		113 Nh Nihonium (286)		114 Fl Flerovium (289)		115 Mc Moscovium (288)		116 Lv Livermorium (293)		117 Ts Tennessine (294)		118 Og Oganesson (294)	
Lanthanide Series				57 La Lanthanum 138.905		58 Ce Cerium 140.12		59 Pr Praseodymium 140.908		60 Nd Neodymium 144.24		61 Pm Promethium 144.913		62 Sm Samarium 150.36		63 Eu Europium 151.964		64 Gd Gadolinium 157.25		65 Tb Terbium 158.925		66 Dy Dysprosium 162.50		67 Ho Holmium 164.930		68 Er Erbium 167.259		69 Tm Thulium 168.934		70 Yb Ytterbium 173.055		71 Lu Lutetium 174.967			
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Recap: Ions

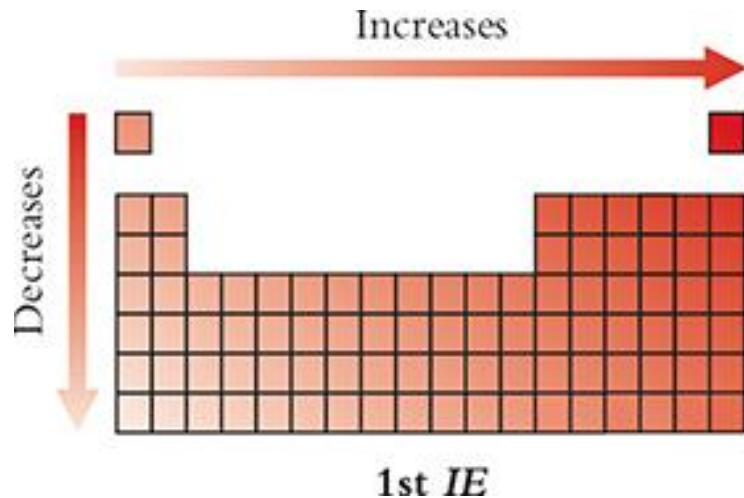
- Atoms tend to form **ions** (a neutral atom that gains or gives up electrons) in an attempt to achieve a **stable octet**
 - **Cations**— positive charged
 - **Anions**— negative charged
- **Metals** in the main group elements tend to **give up** electrons forming **cations** that have the same number of electrons as the nearest **noble gas**
- **Non-metals** tend to **gain** electrons and form **anions** that have the same number of electrons as the nearest **noble gas**



General Trend: #2 Ionization Energy (IE)

Ionization E: The amount of energy required to remove an electron

- Moving **down** a group, the **IE** ↓
 - As **n** ↑, valence electrons are farther from the positive attractive force of the nucleus
 - **Less energy** is required to remove the electron (easier)
- **Across** a period (left to right), the **IE** ↑
 - As **Z** ↑, the attraction between the nucleus and valence electrons increases
 - **More energy** is required to remove the electron (harder)




2nd and 3rd Ionization Energies

IE_1 = Removing the 1st electron

IE_2 = Removing the 2nd electron

IE_3 = Removing the 3rd electron

Process	Configurations	<i>IE</i>
$\text{Mg(g)} \rightarrow \text{Mg}^+(\text{g}) + \text{e}^-$	$[\text{Ne}]3s^2 \rightarrow [\text{Ne}] 3s^1$	739 kJ/mol
$\text{Mg}^+(\text{g}) \rightarrow \text{Mg}^{2+}(\text{g}) + \text{e}^-$	$[\text{Ne}] 3s^1 \rightarrow [\text{Ne}]$	1450 kJ/mol
$\text{Mg}^{2+}(\text{g}) \rightarrow \text{Mg}^{3+}(\text{g}) + \text{e}^-$	$[\text{Ne}] \rightarrow [\text{He}] 2s^2 2p^5$	7730 kJ/mol



When increasing the positive charge on an atom, this results in:

Increased energy required to remove each electron (more difficulty)

Example: Trends in Ionization Energy

wooclap



Rank the following atoms in order of increasing first IE (smallest to biggest)

a) F, Li, C

1																	18																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
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39.098	40.078	44.956	47.867	50.942	51.996	54.938	55.845	58.933	58.693	63.546	65.38	69.723	72.631	74.922	78.971	79.904	83.798																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Rubidium	Strontium	Yttrium	Zirconium	Niobium	Molybdenum	Technetium	Ruthenium	Rhodium	Palladium	Silver	Cadmium	Indium	Tin	Antimony	Tellurium	Iodine	Xenon																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
85.468	87.62	88.906	91.224	92.906	95.95	98.907	101.07	102.906	106.42	107.868	112.414	114.818	118.711	121.760	127.6	126.904	131.294																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
55	Cs	56	Ba	57-71	Hf	72	W	73	Ta	74	Re	75	Os	76	Ir	77	Pt	78	Au	79	Hg	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Cesium	Barium	Lanthanide Series			Hafnium	Tungsten	Tantalum	Rhenium	Osmium	Iridium	Platinum	Gold	Mercury	Thallium	Lead	Bismuth	Polonium	Astatine	Radon																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
132.905	137.328				178.49	183.84	180.948	186.207	190.23	192.22	195.084	196.967	200.592	204.383	207.2	208.980	209	210	222.018																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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Francium	Radium	Actinide Series			Rutherfordium	Dubnium	Seaborgium	Bohrium	Hassium	Meitnerium	Darmstadtium	Roentgenium	Copernicium	Nihonium	Flerovium	Moscovium	Livermorium	Tennessine	Oganesson																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
Lanthanide Series	Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
	138.905	140.116	140.908	144.24	144.913	150.36	151.964	157.25	158.925	162.50	164.930	167.259	168.934	173.055	174.967																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
Actinide Series	Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							

b) Be, Ba, Mg

What to do when both rules apply?

Arrange the following atoms in order of decreasing first ionization energy: Ar, Cl, Cs, K

Periodic Table of the Elements																		18 VIIIA 8A
1 1A 1A																	2 VIIIA 8A	
1 H Hydrogen 1.008	2 2A 2A															18 VIII 8A		
3 Li Lithium 6.941	4 Be Beryllium 9.012															10 Ne Neon 20.180		
11 Na Sodium 22.990	12 Mg Magnesium 24.305	13 III 3A	14 IV 4A	15 V 5A	16 VI 6A	17 VII 7A	18 VIII 8A											18 VIII 8A
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 83.798	
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.905	54 Xe Xenon 131.294	
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71 Lanthanide Series	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium (209)	85 At Astatine (209)	86 Rn Radon (222)	
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinide Series	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (276)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (282)	112 Cn Copernicium (285)	113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (293)	117 Ts Tennessine (294)	118 Og Oganesson (294)	

Exceptions to Ionization Energy Trend

Stability of electron configurations influences Ionization Energy

Neutral Atom

${}_3\text{Li: } 1s^2, 2s^1$

${}_4\text{Be: } 1s^2, 2s^2$

${}_5\text{B: } 1s^2, 2s^2, 2p^1$

${}_6\text{C: } 1s^2, 2s^2, 2p^2$

${}_7\text{N: } 1s^2, 2s^2, 2p^3$

${}_8\text{O: } 1s^2, 2s^2, 2p^4$

Ion: removal of 1 electron

$\text{Li}^+: 1s^2$

$\text{Be}^+: 1s^2, 2s^1$

$\text{B}^+: 1s^2, 2s^2$

$\text{C}^+: 1s^2, 2s^2$

$\text{N}^+: 1s^2, 2s^2, 2p^2$

$\text{O}^+: 1s^2, 2s^2, 2p^3$

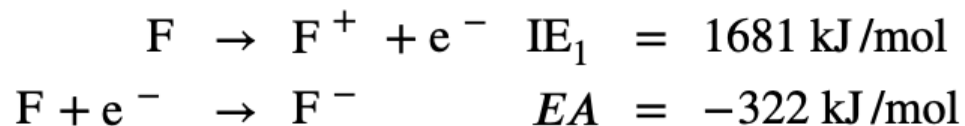
IE: $\text{Li} < \text{B} < \text{Be} < \text{C} < \text{O} < \text{N}$

Increasing I.E. 

General Trend: #3 Electron Affinity

Electron affinity: the energy change when an electron is added to the atom

- Reverse principle of Ionization energy but follows the **same trend**

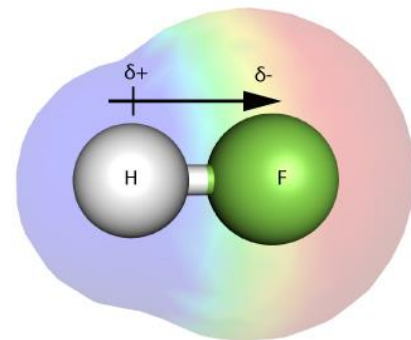
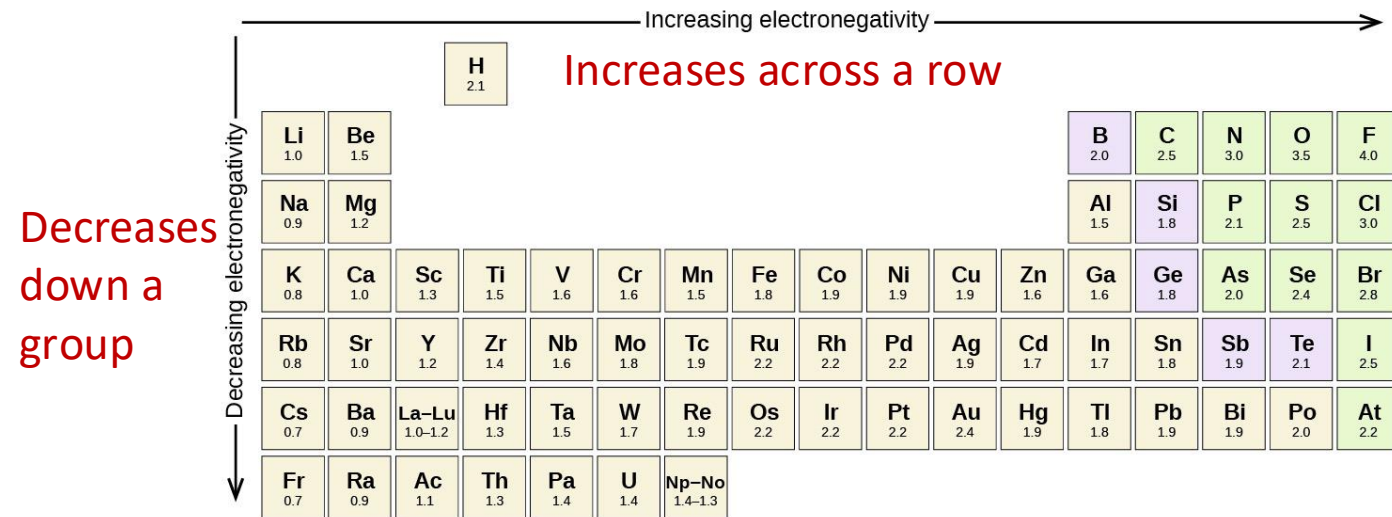


- Moving **down** a group, the **electron affinity** ↓
 - As **n** ↑, there is a greater distance to the nucleus
 - Less attraction for incoming electrons
- Across** a period (left to right), the **electron affinity** ↑
 - As **Z** ↑, the attraction between the nucleus and valence electrons increases
 - Stronger attraction for incoming electrons

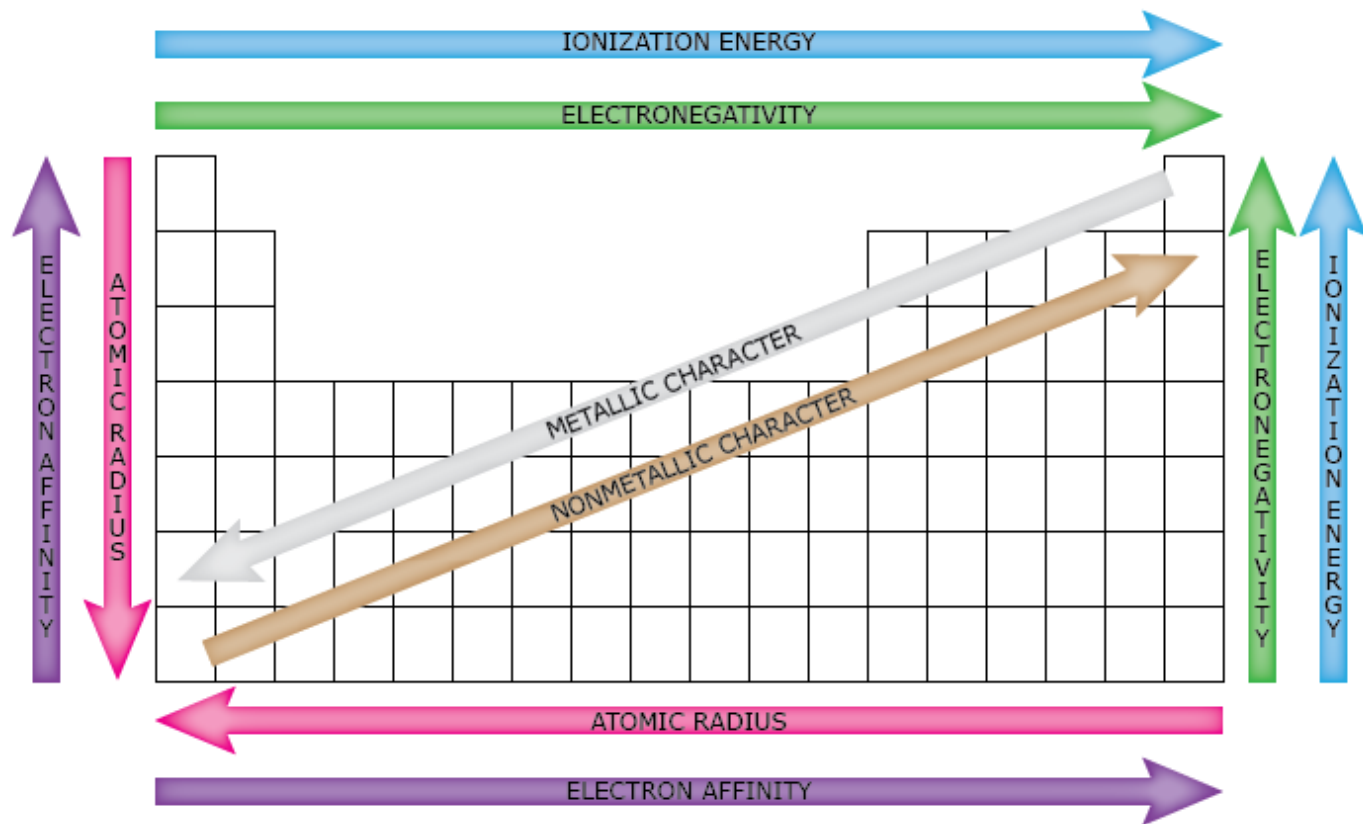
General Trend: #4 Electronegativity

Electronegativity (EN): the tendency of an atom to pull electrons in a chemical bond toward itself

Only applicable when referring to properties of atoms involved in chemical bonding



Overview of Periodic Table Trends



Rules for forming ions

1A																	8A
H																	He
2A																	
Li	Be											B	C	N	O	F	Ne
Na	Mg	3B	4B	5B	6B	7B	8B			1B	2B	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†	(1)	(1)	(1)	(1)	(1)	(1)	(2)	(2)							

Metals

Nonmetals

Metalloids

Noble gases

*

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
----	----	----	----	----	----	----	----	----	----	----	----	----	----

†

Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
----	----	---	----	----	----	----	----	----	----	----	----	----	----

Move electrons onto or off of the atom in order to:

- Fill the entire valence s and p subshells
- Empty the entire valence s and p subshells
- Empty the valence p subshell – only if $n \geq 4$

NEVER add more than 3 electrons

NEVER remove more than:

3 e⁻ from small atoms ($n \leq 3$)

4 e⁻ from large atoms ($n \geq 4$)

Metals NEVER form negative ions

Rules for forming ions

When forming cations, *electrons are always lost **first** from the VALENCE subshells, and only then will they be lost from what were originally inner subshells*

Transition metals (d block elements) do not always follow predictable patterns for what stable ions they form (this is NOT the oxidation state).

- Most will form +2 ions M^{2+} or $M(II)$
- Some will form +1 ions M^{1+} or $M(I)$
- Some will form +3 ions M^{3+} or $M(III)$

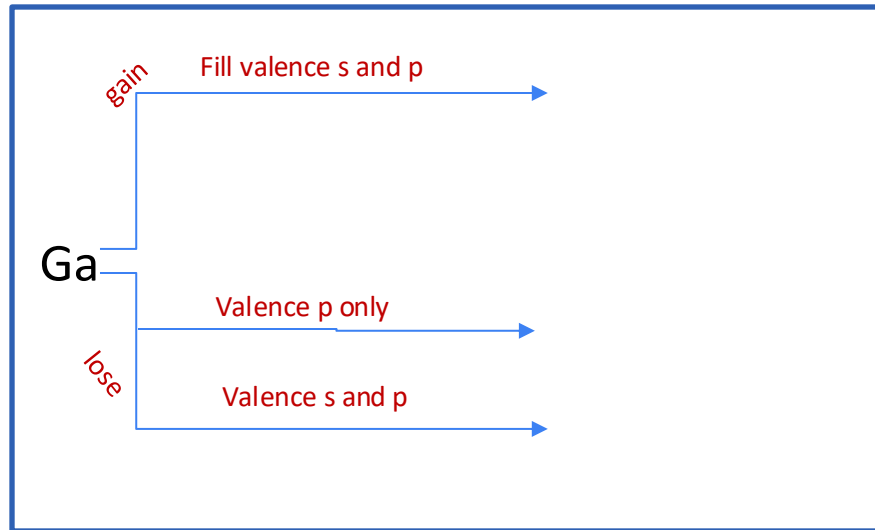
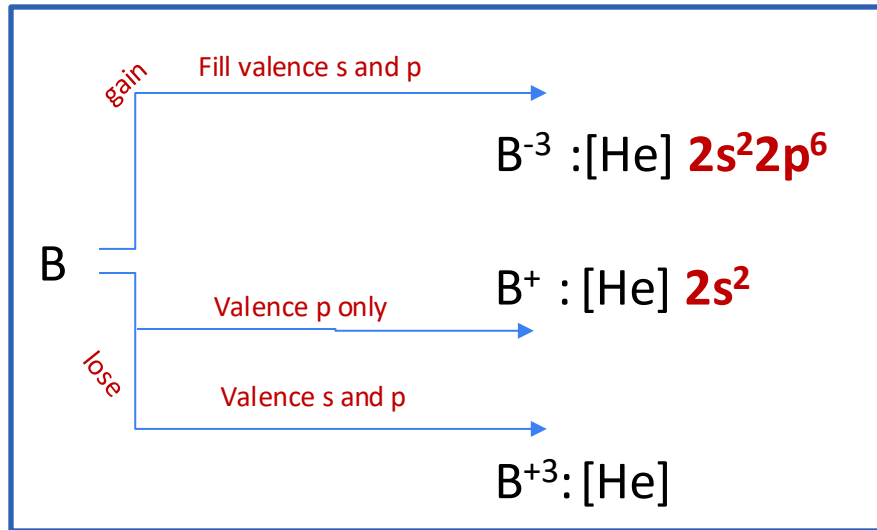
Example: $_{23}V$: $[Ar] 4s^2 3d^3$

$_{23}V(III)$: $[Ar] 4s^0 3d^2$

Example(s): Predict the most likely ion(s) to form for an atom

Circle the possible ions for each atom

wooclap



1. Fill the entire valence s and p subshells
2. Empty the entire valence s and p subshells
3. Empty the valence p subshell – only if $n \geq 4$

NEVER add more than 3 electrons

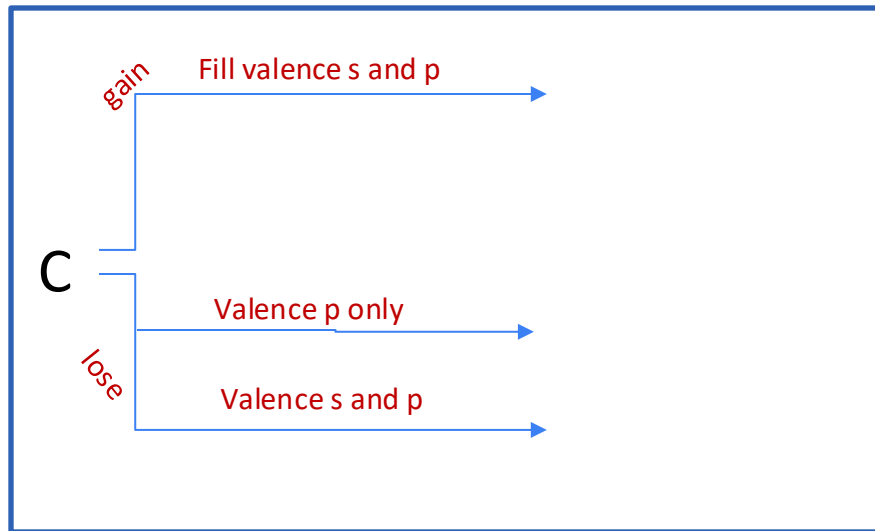
NEVER remove more than: 3 ($n \leq 3$) or 4 ($n \geq 4$)

Metals **NEVER** negative

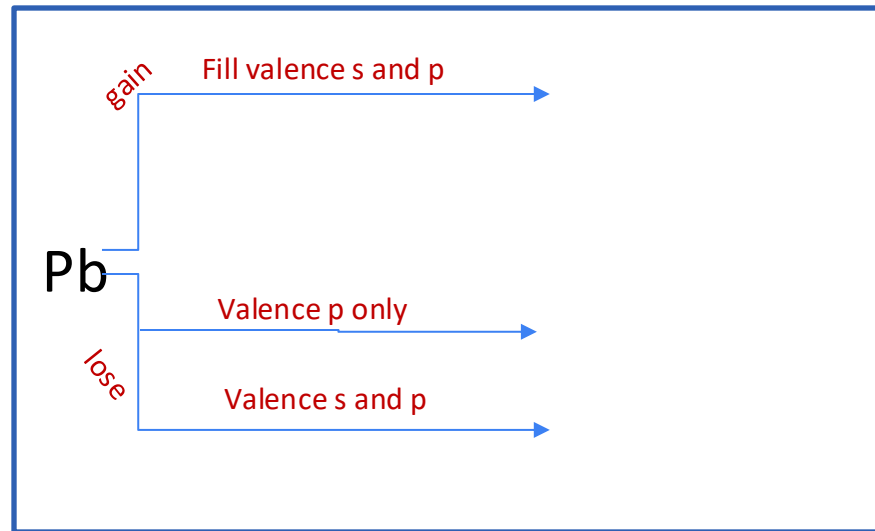
Extra: Predict the most likely ion(s) to form for an atom

Circle the possible ions for each atom

C: [He] $2s^2 2p^2$



Pb: [Xe] $6s^2 5d^{10} 4f^{14} 6p^2$



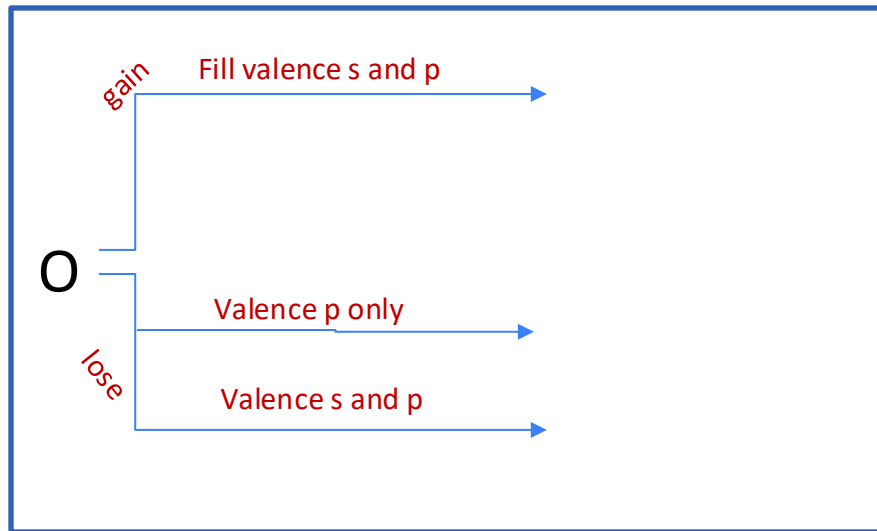
1. Fill the entire valence s and p subshells
2. Empty the entire valence s and p subshells
3. Empty the valence p subshell – only if $n \geq 4$

NEVER add more than 3 electrons

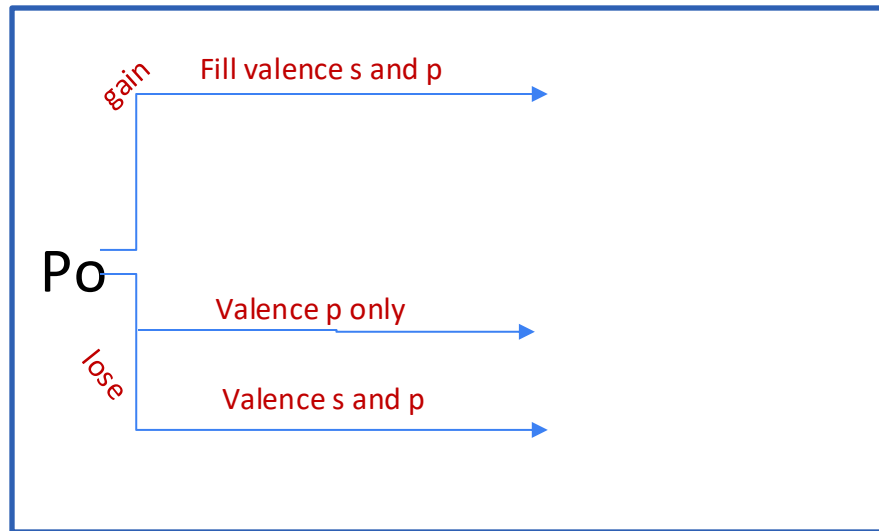
NEVER remove more than: 3 ($n \leq 3$) or 4 ($n \geq 4$)

Metals **NEVER** negative

Extra: Predict the most likely ion(s) to form for an atom



1. Fill the entire valence s and p subshells
2. Empty the entire valence s and p subshells
3. Empty the valence p subshell – only if $n \geq 4$



- NEVER** add more than 3 electrons
- NEVER** remove more than: 3 ($n \leq 3$) or 4 ($n \geq 4$)
- Metals **NEVER** negative

Writing electron configurations for Ions

1. Write configuration for neutral atom & count the number of electrons
2. If ion is negative, add electrons until ion's negative charge is reached
3. If ion is positive, remove electrons until positive charge reached
4. Fill orbitals to match the nearest noble gas of smaller atomic number
5. Add remaining electrons to the next filling orbitals according to Hund's rule
 - For neutral atoms and anions, place electrons in ns before (n-1)d
 - For cations, place electrons in (n-1)d before ns

Note: atoms and ions that have the same number of electrons are **isoelectronic**

e.g. Cr^{3+} configuration?