
Periodic Law
Topic#6
AMSAT Chem 1H

Student Edition

History**Periodicity**
Topic#6
Objectives

Objectives

- **Explain** the roles of Mendeleev and Moseley in the development of the periodic table.
- **Describe** the modern periodic table.
- **Explain** how the periodic law can be used to predict the physical and chemical properties of elements.
- **Describe** how the elements belonging to a group of the periodic table are interrelated in terms of atomic number.

Periodicity
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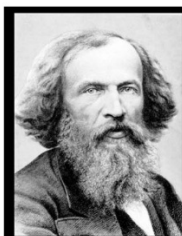
History

• **Mendeleev**

- arranged the known elements by properties and then looked for trends (patterns)
- when arranged by increasing atomic mass, similar properties appeared at regular intervals
 - this repeating interval is considered *periodic*
- created a table where elements with similar properties were grouped together
 - a few elements grouped according to properties had an atomic mass less than the element that preceded it.
 - For example, I was placed after Te even though I has a lower atomic mass than Te)
 - Why was I placed after Te?
 - Other examples include Ni and Co,
- considered the father of the modern periodic table
- procedure left empty spaces where he predicted the existence of new, undiscovered elements and some of their properties

ekasilicon (after silicon)

- predicted properties:	72amu,	5.5g/cm ³	high mp, gray
- real:	72.59amu	5.36g/cm ³	high mp, gray



Dmitri
Ivanovich
Mendeleev

Russia
1871

Periodicity Topic#6

History

<p>H = 1</p> <p>Be = 9,4</p> <p>B = 11</p> <p>C = 12</p> <p>N = 14</p> <p>O = 16</p> <p>F = 19</p> <p>Li = 7 Na = 23</p>	<p>Mg = 24</p> <p>Al = 27,4</p> <p>Si = 28</p> <p>P = 31</p> <p>S = 32</p> <p>Cl = 35,5</p> <p>K = 39</p> <p>Ca = 40</p> <p>? = 45</p> <p>?Er = 56</p> <p>?Yt = 60</p> <p>?In = 75,6</p>	<p>Ti = 50</p> <p>V = 51</p> <p>Cr = 52</p> <p>Mn = 55</p> <p>Fe = 56</p> <p>Ni = Co = 59</p> <p>Cu = 63,4</p> <p>Zn = 65,2</p> <p>? = 68</p> <p>? = 70</p> <p>As = 75</p> <p>Se = 79,4</p> <p>Br = 80</p> <p>Rb = 85,4</p> <p>Sr = 87,6</p> <p>Ce = 92</p> <p>La = 94</p> <p>Di = 95</p> <p>Th = 118?</p>
		<p>Zr = 90</p> <p>Nb = 94</p> <p>Mo = 96</p> <p>Rh = 104,4</p> <p>Ru = 104,4</p> <p>Pd = 106,6</p> <p>Ag = 108</p> <p>Cd = 112</p> <p>Ur = 116</p> <p>Sn = 118</p> <p>Sb = 122</p> <p>Te = 128?</p> <p>J = 127</p> <p>Cs = 133</p> <p>Ba = 137</p>
		<p>? = 180</p> <p>Ta = 182</p> <p>W = 186</p> <p>Pt = 197,4</p> <p>Ir = 198</p> <p>Os = 199</p> <p>Hg = 200</p> <p>Au = 197?</p> <p>Bi = 210?</p> <p>Tl = 204</p> <p>Pb = 207</p>

Dobereiner's triads
 Known to Mendeleev
 Unknown to Mendeleev

																		H																		
																		1.01																		
He	Li	Be	B	C	N	O	F																													
4.00	6.94	9.01	10.8	12.0	14.0	16.0	19.0																													
Ne	Na	Mg	Al	Si	P	S	Cl																													
20.2	23.0	24.3	27.0	28.1	31.0	32.1	35.5																													
Ar	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni																										
40.0	39.1	40.1	45.0	47.9	50.9	52.0	54.9	55.9	58.9	58.7																										
	Cu	Zn	Ga	Ge	As	Se	Br																													
	63.5	65.4	69.7	72.6	74.9	79.0	79.9																													
Kr	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd																										
83.8	85.5	87.6	88.9	91.2	92.9	95.9	(99)	101	103	106																										
	Ag	Cd	In	Sn	Sb	Te	I																													
	108	112	115	119	122	128	127																													
Xe	Ce	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt																										
131	133	137	139	179	181	184	180	194	192	195																										
	Au	Hg	Tl	Pb	Bi	Po	At																													
	197	201	204	207	209	(210)	(210)																													
Rn	Fr	Ra	Ac	Th	Pa	U																														
(222)	(223)	(226)	(227)	232	(231)	238																														

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History

Properties	Ekaaluminum (gallium, discovered 1875)		Ekaboron (scandium, discovered 1877)		Ekasilicon (germanium, discovered 1886)	
	Predicted	Observed	Predicted	Observed	Predicted	Observed
Density	6.0 g/cm ³	5.96 g/cm ³	3.5 g/cm ³	3.5 g/cm ³	5.5 g/cm ³	5.47 g/cm ³
Melting point	low	30°C	*	*	high	900°C
Formula of oxide	Ea ₂ O ₃	Ga ₂ O ₃	Eb ₂ O ₃	Sc ₂ O ₃	EsO ₂	GeO ₂
Solubility of oxide	*	*	dissolves in acid	dissolves in acid	*	*
Density of oxide	*	*	*	*	4.7 g/cm ³	4.70 g/cm ³
Formula of chloride	*	*	*	*	EsCl ₄	GeCl ₄
Color of metal	*	*	*	*	dark gray	grayish white

Predicted elements	Element and year discovered	Properties	Predicted properties	Observed properties
Ekaaluminum	gallium 1875	density of metal	6.0 g/mL	5.96 g/mL
		melting point	low	30°C
		oxide formula	Ea ₂ O ₃	Ga ₂ O ₃
Ekaboron	scandium 1877	density of metal	3.5 g/mL	3.86 g/mL
		oxide formula	Eb ₂ O ₃	Sc ₂ O ₃
		solubility of oxide	dissolves in acid	dissolves in acid
Ekasilicon	germanium 1886	melting point	high	900°C
		density of metal	5.5 g/mL	5.47 g/mL
		color of metal	dark gray	grayish white
		oxide formula	EsO ₂	GeO ₂
		density of oxide	4.7 g/mL	4.70 g/mL
		chloride formula	EsCl ₄	GeCl ₄

History

The Modern Periodic Table

- **Mosely**
 - worked with Rutherford, discovered atomic number, arranged periodic table according to atomic number, confirmed the broken pattern (Te/I and Co/Ni) of Mendeleev, and confirmed the ordering of elements by properties.
- **periodic law**
 - The physical and chemical properties of elements are periodic functions of their atomic numbers.
- **Noble Gases (Group 18)**
 - Argon was discovered by English physicist John William Strutt (Lord Rayleigh) and Scottish chemist Sir William Ramsey.
 - Soon afterward He was discovered
 - Ramsey proposed that a new group needed to be added between the fluorine family (group 17) and the lithium family (group 1) thus creating group 18, The Noble gases.
- **Lanthanides (4f's)**
 - 14 elements from cerium, Ce (58) and lutetium, Lu (71)
 - Incredibly similar in physical and chemical properties, found together in the earth and very hard to separate from each other.
- **Actinides (5f's)**
 - 14 elements from thorium, Th (90) and lawrencium, Lr (103)
 - All are radioactive and most are man made (only thorium, protactinium, uranium are found in nature with the others being solely synthetic)

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History

IA ¹																	VIIA ³	Zero ⁴	
H 1	IIA ²											IIIA	IVA	VA	VIA	H 1	He 2		
Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10		
Na 11	Mg 12	IIIB	IVB	VB	VIB	VIIB	VIII				IB	IIB	Al 13	Si 14	P 15	S 16	Cl 17	Ar 18	
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36		
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54		
Cs 55	Ba 56	*La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86		
Fr 87	Ra 88	Ac 89	Unq 104	Unp 105	Umh 106														

Noble Gases

*Lanthanide series	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71	Lanthanides
*Actinide series	Th 90	Pu 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103	Actinides

¹Group IA (excluding hydrogen) comprises the alkali metals. ³Group VIIA (excluding hydrogen) comprises the halogens.
²Group IIA comprises the alkaline-earth metals. ⁴Group zero comprises the noble gases.
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History

Periodicity

- With respect to atomic number can be found in any group.

	Element and atomic number	Difference in atomic numbers		Element and atomic number	Difference in atomic numbers
Group 18	He 2	8	Group 1	Li 3	8
	Ne 10			Na 11	
	Ar 18	18		K 19	
	Kr 36			Rb 37	
	Xe 54	18		Cs 55	
	Rn 86			Fr 87	
				32	

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Lab: It's in the Cards

Reading a card

ionization energy (IE)
(energy needed to remove an electron)

atomic mass the weighted (by mass) average of the naturally occurring isotopes of an element.
(Cu = 65.546amu)

formula of its chloride

density

electronegativity (a measure of how strongly the atom holds onto its electron in a bond)

590	0.20
40.1	XO
XCl ₂	1112
1.55	XH ₂
1.00	

atomic radius (the distance from the center of the atom to its outermost electron)

formula of its oxide

melting point (mp)

formula of its hydride

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Lab: It's in the Cards

<u>Property</u>	<u>Na</u>	<u>Mg</u>	<u>Al</u>	<u>Si</u>	<u>P</u>	<u>S</u>	<u>Cl</u>	<u>Ar</u>
Electronegativity	1.0	1.3	1.6	1.9	2.2	2.6	3.2	--
Atomic Mass (amu)	23	24	27	28	31	32	35	40
Atomic Radius (Å)	2.23	1.72	1.82	1.46	1.23	1.09	0.97	0.88
mp(K)	371	923	933	1687	317	388	172	84
I_E (kJ/mol)	496	738	578	787	1012	1000	1251	1521
Density	0.97g/cm ³	1.7g/cm ³	2.7g/cm ³	2.3g/cm ³	1.8g/cm ³	2.1g/cm ³	3.2g/L	1.8g/L

<u>Element</u>	<u>At Mass (amu)</u>	<u>At Radius (Å)</u>	<u>MP(K)</u>	<u>I_E(kJ/mol)</u>	<u>EN</u>	<u>Density</u>
Li/F	7/19	2.05/0.57	454/54	520/1681	1.0/4/0	0.53(g/cm ³)/1.70(g/L)
Na/Cl	23/35	2.23/0.97	371/172	496/1251	1.0/3.2	0.97(g/cm ³)/3.2(g/L)
K/Br	39/80	2.77/1.12	337/266	419/1140	0.8/3.0	0.86(g/cm ³)/3.1(g/cm ³)
Rb/I	85/127	2.98/1.32	312/387	403/1008	0.8/2.7	1.5(g/cm ³)/4.9(g/cm ³)
Cs	133	3.34	302	376	0.7	1.9(g/cm ³)

It's in the Cards Lab

Li							F
Na	Mg	Al	Si	P	S	Cl	Ar
K						Br	
Rb						I	
Cs							

Objectives

- **Describe** the relationship between electrons in sublevels and the length of each period of the periodic table.
- **Locate** and name the four blocks of the periodic table. Explain the reasons for these names.
- **Discuss** the relationship between group configurations and group numbers.
- **Describe** the locations in the periodic table and the general properties of the alkali metals, alkaline earth metals, halogens, and noble gases.

Electron Configuration and Periodic Table**Periodicity
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Alkali Metals

- Group 1, most reactive metals, form 1+ ions, ns^1 , valence 1

Alkaline Earth metals

- Group 2, reactive metals, form 2+ ions, ns^2 , valence 2

Hydrogen

- 1 valence, nonmetal, forms 1+ and 1- ions, ns^1

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Electron Configuration and Periodic Table

Sample WS#1 - Using Electron Configuration s-block Elements

1. Without looking at the periodic table, give the group (___), period (___), and block (___) in which the element with the electron configuration $[\text{Xe}]6s^2$ is located.
2. Without looking at the periodic, write the electron configuration for the group 1 element in the third period. Is this element likely to be more active or less active than the element described in question 1?
3. Without looking at the periodic table, give the group (___), period (___), and block (___) in which element with the electron configuration $[\text{Kr}]5s^1$ is located.
4. Without looking at the periodic table, write the complete electron configuration for the group 2 element in the fourth period.
5. Without looking at the periodic table, give the group configuration for the group 2 elements.

Electron Configuration and Periodic Table**Periodicity
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Transition Elements (all metals)

- the *d*-block elements: Groups 3-12
- group configuration for these elements is $(n-1)d^{1-10}ns^2$
 - 4th row transition metals: $4-1 = 3$ so $3d^{1-10}4s^2$
 - i.e. Ti is $3d^24s^2$
- good conductors of heat and electricity
- some are not reactive: Pt, Au, and Pd
- a few can exist in nature as free elements (Au and Pt)
- coinage metals: Cu, Ag, and Au

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Electron Configuration and Periodic Table

***d*-block Elements**

6. An element has the electron configuration $[\text{Kr}]4d^65s^1$. Without looking at the periodic table, identify the period (___), block (___), and group (___) in which the element is located. Then consult the periodic table to identify this element and the others in its group.
7. Without looking at the periodic table, identify the period (___), block (___), and group (___) in which this element with the electron configuration $[\text{Ar}]3d^84s^2$ is located.
8. Without looking at the periodic table, write the outer electron configuration for the group 12 element in the fifth period.
9. Refer to the periodic table to identify the element described in question 8 and write the element's Noble-gas notation.

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Electron Configuration and Periodic Table

The *p*-block elements (metals, metalloids, and nonmetals)

- outer electron config - ns^2np^{1-6}
- valence 3-8
 - bromine in group 17 : val = 17-10 = 7
- includes all of the nonmetals except He and H
- includes all of the metalloids: B, Si, Ge, Te, As, and Sb
- *p*-block metals can lose their *s* and *p* electrons to form ions
 - Sn has an outer electron config of $5s^24d^{10}5p^2$
 - tin ions are Sn^{2+} (2 *p* electrons lost) and Sn^{4+} (2 *p* and 2 *s* electrons lost)
- Group 17
 - halogens, ns^2np^5 , valence of 7, form (1-) ions, most reactive nonmetals, fluorine is the most reactive nonmetal
- Group 18
 - Noble gases, inert (do not react: Kr, Xe, and Rn can react with Cl, F, and O at high temperatures and pressures),

Main group elements (representative elements) - *s* and *p*-block elements

Valence electrons:	1	2		3	4	5	6	7	8
Bonding:	1	2		3	4	3	2	1	0

Electron Configuration and Periodic Table**Periodicity
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***p*-block Elements**

10. Without looking at the periodic table, write the outer electron configuration for the group 17 element in the third period.
11. Name the element described in question 10, and identify it as a metal, metalloid, or nonmetal.
12. Without looking at the periodic table, identify the period (___), block (___), and group (___) of an element with the electron configuration $[\text{Ar}]3d^{10}4s^24p^3$.
13. Name the element described in question 12, and identify it as a metal, metalloid, or nonmetal.

Electron Configuration and Periodic Table**Periodicity**
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f-block Elements

- lanthanides and actinides
- all actinides are radioactive
- all very similar in properties, so they are very hard to separate when mined
- similar to group 2 in properties
- actinides first three are naturally occurring others are person-made

Electron Configuration and Periodic Table

Review: The Element Blocks of the Periodic Table

14. The electron configuration of atoms of four elements are written below. For each element, name the block and group in which it is located. Then name the element by consulting the periodic table. Identify each element as a metal, metalloid, or nonmetal. Finally, describe it as likely to be of high reactivity or of low reactivity.

	<u>Block</u>	<u>Period</u>	<u>Group</u>	<u>Group name</u>	<u>Element</u>	<u>Type</u>	<u>Reactivity</u>
a. $[\text{Xe}]4f^{14}5d^96s^1$	d	6	10	transition metals	Pt	metal	low
b. $[\text{Ne}]3s^23p^5$							
c. $[\text{Ne}]3s^23p^6$							
d. $[\text{Ar}]3d^{10}4s^2 4p^2$							
e. $[\text{He}]2s^22p^5$							
f. $[\text{Ar}]3d^{10}4s^1$							
g. $[\text{Kr}]5s^2$							

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Periodic Trends

Atomic Radius (A_r) - distance from center of atom to outer most electron.

Ionic Radius (I_r) - half the distance between two ionically bonded atoms (ions, transfer of electrons from metal to nonmetal)

Ionization Energy (IE) - the amount of energy needed to remove an electron from a gaseous atom.

Electron Affinity (A_e) - the energy change when a gaseous atom accepts an electron

Electronegativity (EN) - measures the ability of an atom to hold on to its electron when in a bond.

Metallic Character (M_c) - the level of reactivity of a metal

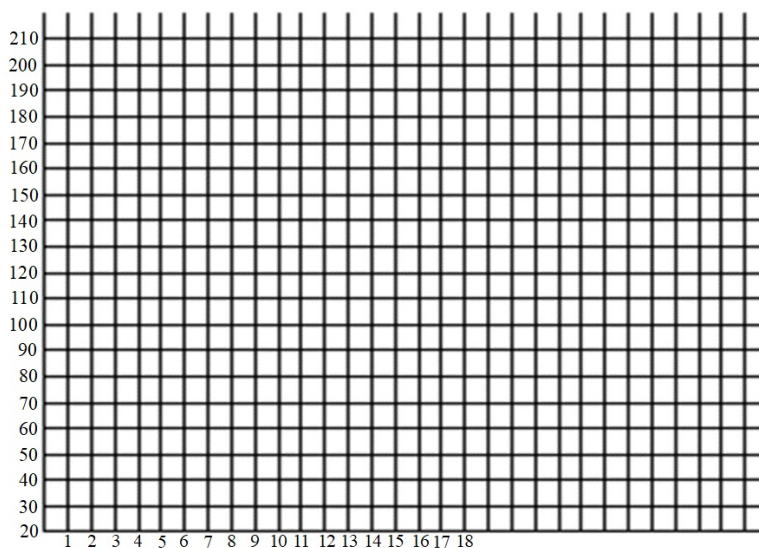
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Periodic Trends - Atomic Radius (A_r)

Periodic Trends Graphing Activity/Study Aide

Need: 2 pieces of double sided graph paper and Periodic Trends Study Sheet

Element	Atomic Radius*	Element	Atomic Radius*
H	53	Ne	38
He	31	Na	190
Li	167	Mg	145
Be	112	Al	118
B	87	Si	111
C	67	P	98
N	56	S	88
O	48	Cl	79
F	42	Ar	71



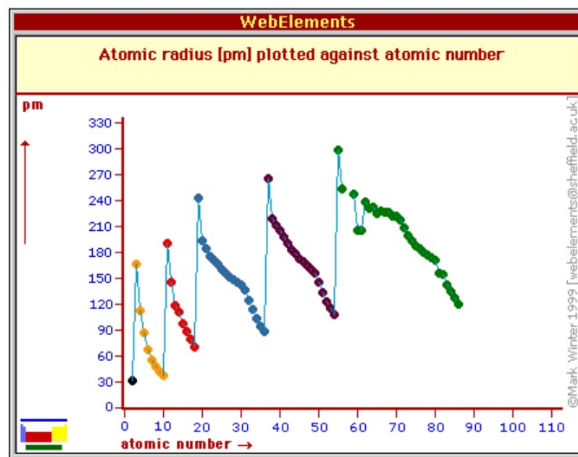
*Atomic radius is measured in picometers (pm)

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Periodic Trends - Atomic Radius (A_r)

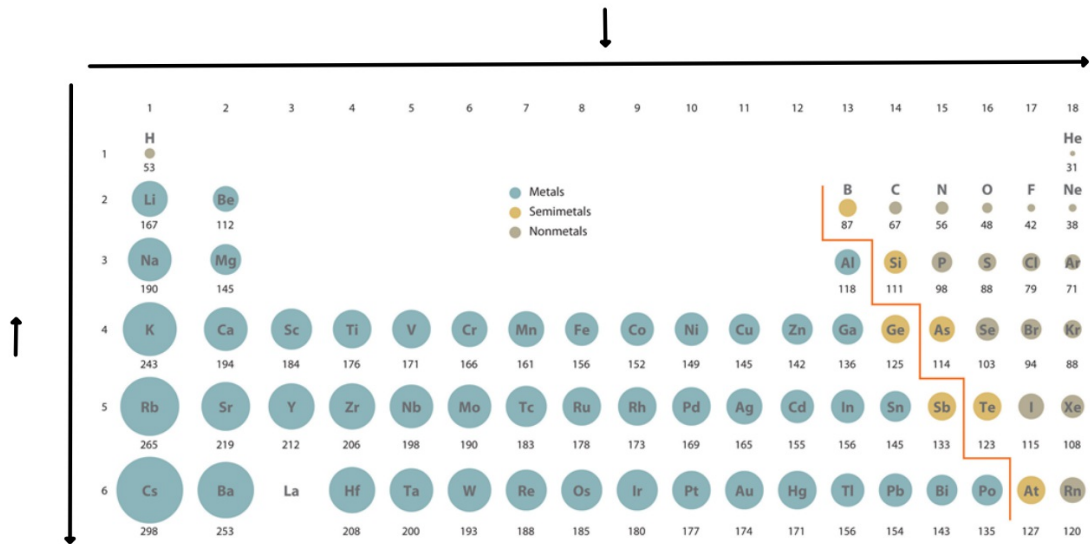
Trend for atomic radius

- decreases across a period
 - Why? electrons move into the same energy level with more protons in nucleus pulling them towards the center of the atom (an increase in coulombic force due to increase in nuclear charge decreases distance between nucleus and outer electron(s))
- increases down a group
 - Why? Each move down increases the number of energy levels the atom has (more shells) (decrease in coulombic force due to an increase in distance between nucleus and outer electron(s))



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Periodic Trends - Atomic Radius (A_r)



Periodicity Topic#6

Periodic Trends - Atomic Radius (A_r)

Sample WS#2 - Periodic Trends

1. Of the elements Mg, Cl, Na, and P, which has the largest atomic radius? Smallest? Explain your answer in terms of trends in the periodic table.
2. Of the elements Ca, Be, Ba, and Sr, which has the largest atomic radius? Smallest? Explain your answer in terms of trends in the periodic table

Periodic Table of the Elements

The periodic table includes the following elements and their atomic masses (where available):

Group	1	2	3-10	11	12	13	14	15	16	17	18							
Label	IA	IIA	IIIB-10B	IB	IIB	IIIA	IIIVA	IIVA	VIA	VIIA	VIIIA							
1	H (1.008)										He (4.003)							
2	Li (6.941)	Be (9.012)									Ne (20.180)							
3	Na (22.990)	Mg (24.305)									Ar (39.948)							
4	K (39.098)	Ca (40.078)	Sc (44.956)	Ti (47.867)	V (50.942)	Cr (51.996)	Mn (54.938)	Fe (55.845)	Co (58.933)	Ni (58.693)	Cu (63.546)	Zn (65.38)	Ga (69.723)	Ge (72.631)	As (74.922)	Se (78.971)	Br (79.904)	Kr (83.798)
5	Rb (85.468)	Sr (87.62)	Y (88.906)	Zr (91.224)	Nb (92.906)	Mo (95.94)	Tc (98.906)	Ru (101.07)	Rh (101.07)	Pd (106.42)	Ag (107.868)	Cd (112.411)	In (114.818)	Sn (118.710)	Sb (121.760)	Te (127.6)	I (126.905)	Xe (131.29)
6	Cs (132.905)	Ba (137.327)		Hf (178.49)	Ta (180.948)	W (183.84)	Re (186.207)	Os (190.23)	Ir (192.22)	Pt (195.084)	Au (196.967)	Hg (200.592)	Tl (204.383)	Pb (207.2)	Bi (208.980)	Po (209)	At (210)	Rn (222)
7	Fr (223)	Ra (226)		Rf (261)	Db (262)	Sg (266)	Bh (264)	Hs (269)	Mt (268)	Ds (271)	Rg (272)	Cn (285)	Uut (288)	Fl (289)	Uup (294)	Lv (293)	Uus (294)	Uuo (294)
Lanthanide Series	La (138.905)	Ce (140.116)	Pr (140.908)	Nd (144.242)	Pm (144.913)	Sm (150.36)	Eu (151.964)	Gd (157.25)	Tb (158.925)	Dy (162.500)	Ho (164.930)	Er (167.259)	Tm (168.934)	Yb (173.054)	Lu (174.967)			
Actinide Series	Ac (227)	Th (232)	Pa (231)	U (238)	Np (237)	Pu (244)	Am (243)	Cm (247)	Bk (247)	Cf (251)	Es (252)	Fm (257)	Md (258)	No (259)	Lr (260)			

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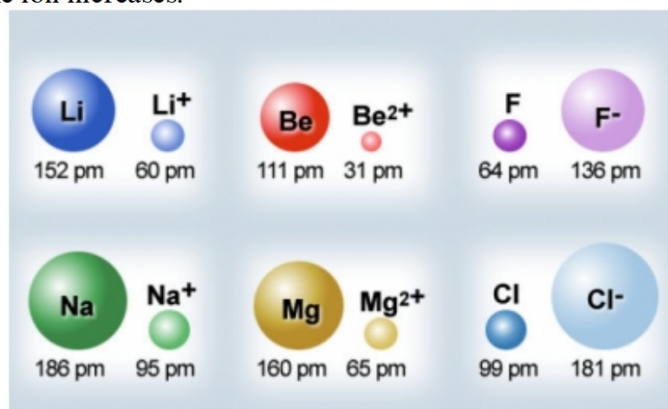
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Periodic Trends - Ionic Radius (I_r)

What occurs to the radius of an atom as it gains or loses electrons (becomes an ion)?

- Loses electrons - becomes a cation ($A \rightarrow A^+ + e^-$).
 - the protons outnumber the electrons, so the electron-electron repulsion forces decrease allowing the protons to pull the outer electrons closer to the nucleus, thus decreasing the radius of the ion.
- Gains electrons - becomes an anion ($A + e^- \rightarrow A^-$).
 - the electrons outnumber the protons, so the electron-electron repulsion forces increase forcing the electrons to move farther apart while the protons have less pull on the electrons. Since the protons have less pull on the outer electrons, the radius of the ion increases.

Question: Which ion is larger Fe^{3+} or Fe^{2+} ? Why?

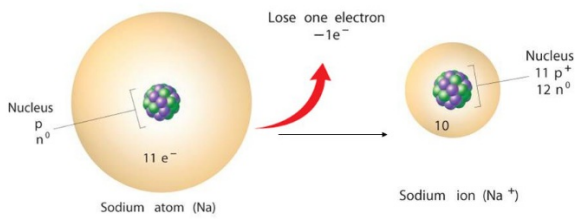


Periodic Trends - Ionic Radius (I_r)

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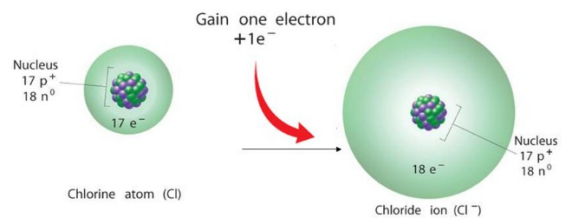
Trends in Ionic Size

Positive and negative ions form when electrons are transferred between atoms.



Trends in Ionic Size

Positive and negative ions form when electrons are transferred between atoms.

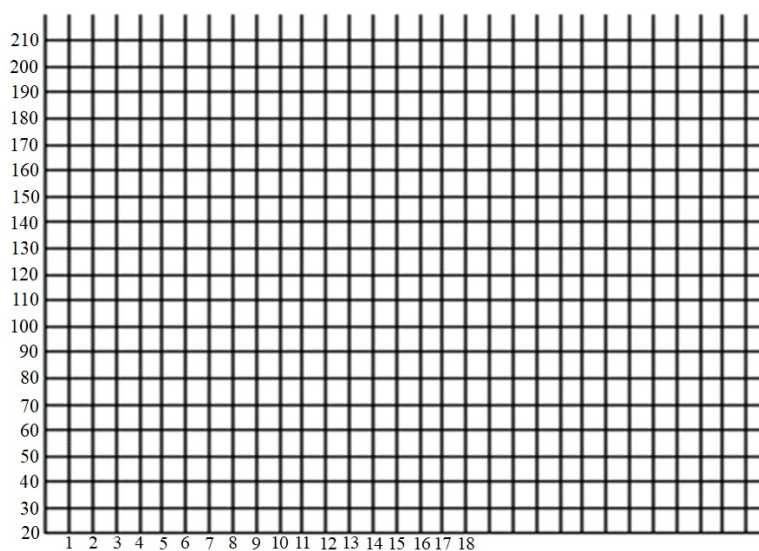


Periodic Trends - Ionic Radius (I_r)

Element	Ionic Radius*	Element	Ionic Radius*
Li ⁺	68	Na ⁺	97
Be ²⁺	31	Mg ²⁺	66
B ³⁺	23	Al ³⁺	51
C	-	Si	-
N ³⁻	171	P ³⁻	212
O ²⁻	140	S ²⁻	184
F ¹⁻	133	Cl ¹⁻	181

*Ionic radius is measured in picometers (pm)

Periodicity Tonic#6

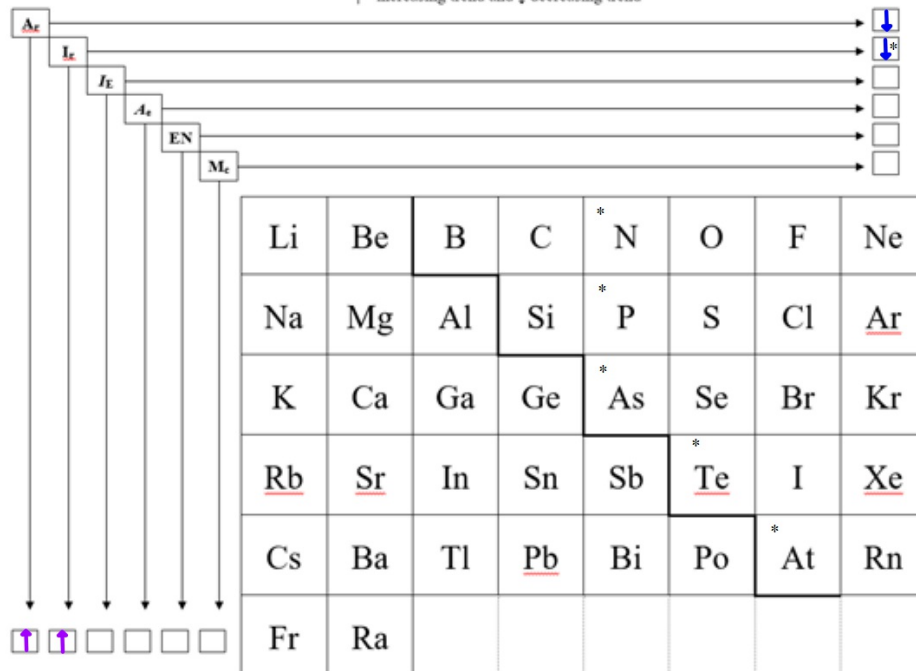


Periodicity Topic#6

Periodic Trends - Ionic Radius (I_r)

Periodicity Topic#6 Trends Study Aide

A_r – atomic radius, I_r – ionic radius, I_E – ionization energy, A_e – electron affinity, EN – electronegativity, and M_c – metallic character
 ↑ - increasing trend and ↓ decreasing trend



*decreases through cations, then balloons when the anions are encountered then starts to decrease again

Periodicity
Topic#6

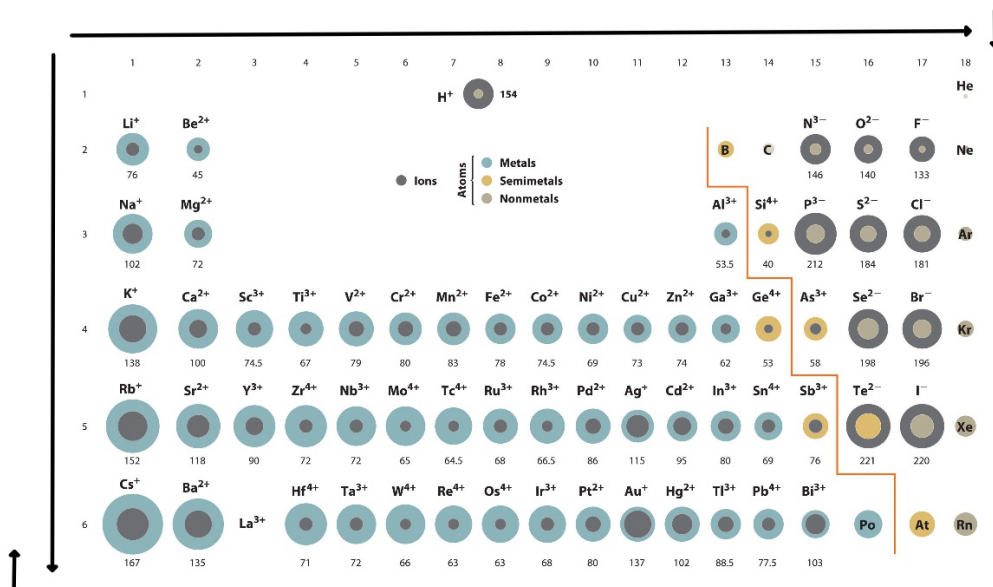
Periodic Trends - Ionic Radius (I_r)

- decreases across a period, but jumps in radius when moving through the metalloids into the nonmetals.
 - Why? Same as above. (an increase in coulombic force due to increase in nuclear charge decreases distance between nucleus and outer electron(s))
 - decreases through cations in a period then expands greatly with the anions in a period then starts to decrease as one moves to the end of the period.
 - Metals form cations (positive ions) which are smaller than their atoms.
 - Nonmetals form anions (negative ions) which are larger than their atoms.
- increases down a group
 - Why? Same as above. (decrease in coulombic force due to an increase in distance between nucleus and outer electron(s))

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

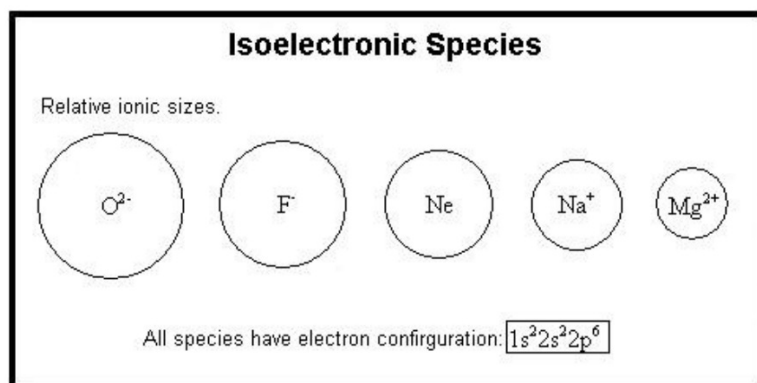
Periodicity
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Periodic Trends - Ionic Radius (I_r)



$Fe^{3+} = 23e^-$
 $Fe^{2+} = 24e^-$
 $Fe^{1+} = 25e^-$
 $Fe^0 = 26e^-$

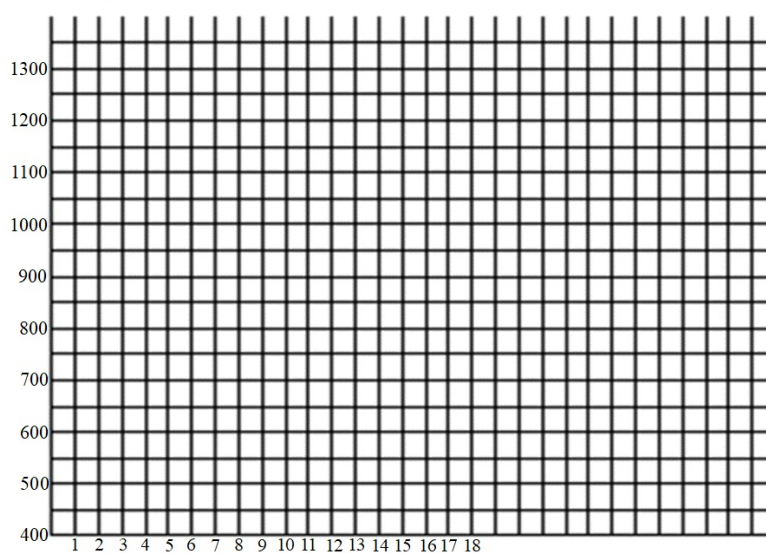
$Fe^{3+} < Fe^{2+} < Fe^{1+} < Fe$



Periodic Trends - Ionization Energy (IE)

Element	IE ₁ *	Element	IE ₁ *
Li	520	Na	496
Be	899	Mg	738
B	801	Al	578
C	1086	Si	787
N	1420	P	1012
O	1314	S	1000
F	1681	Cl	1251

*Ionization energy (IE) is in kJ/mol

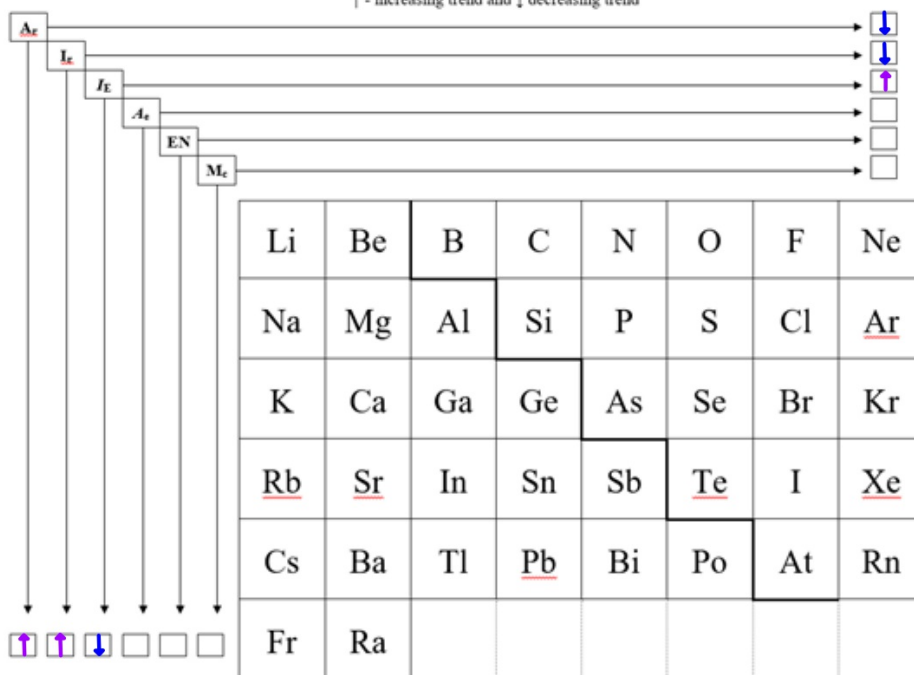
**Periodicity
Tonic#6**

Periodic Trends - Ionization Energy (IE)

**Periodicity
Topic#6**

Periodicity **Topic#6** Trends Study Aide

A_r – atomic radius, I_r – ionic radius, I_E – ionization energy, A_e – electron affinity, EN – electronegativity, and M_c – metallic character
 ↑ - increasing trend and ↓ decreasing trend



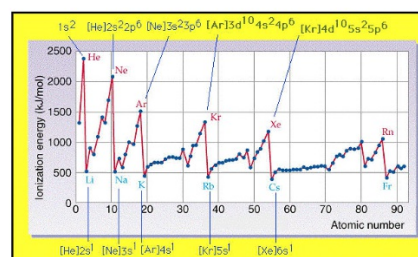
Periodicity Topic#6

Periodic Trends - Ionization Energy (IE)

- The E required to remove one electron from a neutral atom
- $A + \text{energy} \rightarrow A^+ + e^-$ (cation formation)
 - $IE_1 < IE_2 < IE_3 < \text{etc.}$

Trend

- period: ionization energy increases across
 - Why? Pull of nucleus on outer electrons increases, harder to remove. (an increase in coulombic force due to increase in nuclear charge decreases distance between nucleus and outer electron(s))
- group: ionization energy decreases down
 - Why? Outer electrons are further from nucleus, easier to remove (decrease in coulombic force due to an increase in distance between nucleus and outer electron(s))



Periodic Trends - Ionization Energy (*IE*)

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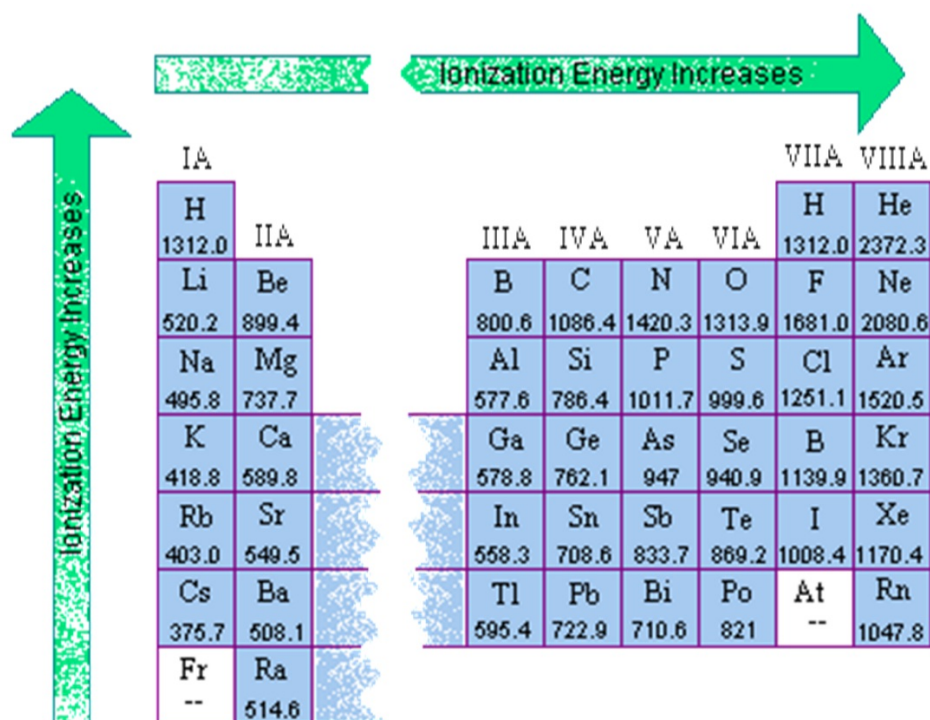
General increase →

Successive Ionization Energies for Period 3 Elements							
Element	IE ₁	IE ₂	IE ₃	IE ₄	IE ₅	IE ₆	IE ₇
Na	498	4560	6910	9540	13 400	16 600	20 100
Mg	736	1445	7730	10 600	13 600	18 000	21 700
Al	577	1815	2740	11 600	15 000	18 310	23 290
Si	787	1575	3220	4350	16 100	19 800	23 800
P	1063	1890	2905	4950	6270	21 200	25 400
S	1000	2260	3375	4565	6950	8490	27 000
Cl	1255	2295	3850	5160	6560	9360	11 000
Ar	1519	2665	3945	5770	7230	8780	12 000

← General decrease

Periodic Trends - Ionization Energy (IE)

Periodicity
Topic#6

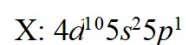
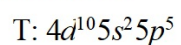
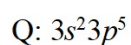


3. Consider the two main-group elements A and B. Element A has a first IE_1 of 419 kJ/mol. Element B has an IE_1 of 1000 kJ/mol. For each element, decide if it is more likely to be in the *s*-block or *p*-block. Which element is more likely to form a positive ion?

Periodic Trends - Ionization Energy (IE)

**Periodicity
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4. Consider the four hypothetical main-group elements Q, R, T, and X with the outer electron configuration indicated below. Then answer the questions that follow.



a. Identify the block locations of each hypothetical main-group element.

b. Which of these elements are in the same period? Same group?

c. Which element would you expect to have the highest IE_1 ? Which would have the lowest IE_1 ?

d. Which element would you expect to have the highest IE_2 ?

e. Which of the elements is most likely to form a 1^+ ion?

Periodicity
Topic#6

Periodic Trends - Electron Affinity (A_e)

- the energy change when a gaseous atom accepts an electron.
- $A + e^- \rightarrow A^{1-} + \text{energy}$ (anion formation)
 - usually a negative number (release of energy)
 - if number is zero or positive, energy needed to add electron (ion unstable)

Trend

- energy released (increase in electron affinity) increases across a period
 - Why? Shielding of nucleus by inner electrons decreases allowing for a stronger attraction between added electron and nucleus. Stronger attraction, more energy released. Atoms closer to an octet.
 - An increase in coulombic attraction due to decreased distance allows the added electron to "drop" to a lower energy level releasing more energy.
- decreases down a group
 - Why? Greater shielding of nuclear charge (positive charge) by the inner electrons.
 - A decrease in coulombic attraction due to increased distance. The drop to a lower energy level is not as great due to the lower coulombic force on the added electron.

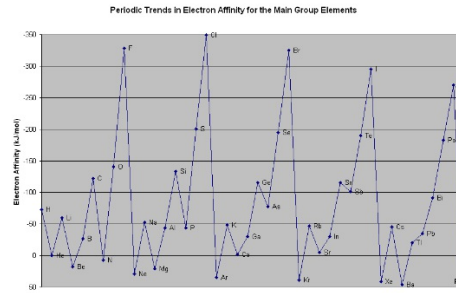
Periodicity Topic#6

Periodic Trends - Electron Affinity (A_e)

Electron affinities in the periodic table

Group →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Period	H 73																	He *
2	Li 60	Be *											B 27	C 122	N *	O 141	F 328	Ne *
3	Na 53	Mg *											Al 42	Si 134	P 72	S 200	Cl 349	Ar *
4	K 48	Ca 2	Sc 18	Ti 8	V 51	Cr 65	Mn *	Fe 15	Co 64	Ni 112	Cu 119	Zn *	Ga 41	Ge 119	As 79	Se 195	Br 324	Kr *
5	Rb 47	Sr 5	Y 30	Zr 41	Nb 66	Mo 72	Tc *	Ru 101	Rh 110	Pd 54	Ag 128	Cd *	In 39	Sn 107	Sb 101	Te 190	I 295	Xe *
6	Cs 46	Ba 14	**	Hf 31	Ta 79	W *	Re 104	Os 150	Ir 205	Pt 223	Au *	Hg 36	Tl 35	Pb 91	Bi *	Po *	At *	Rn *
7	Fr *	Ra *	**	Rf *	Db *	Sg *	Bh *	Hs *	Mt *	De *	Rg *	Cn *	Uut *	Ff *	Uup *	Lv *	Uus *	Uuo *
* Lanthanides			La 45	Ce 92	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu 33	
** Actinides			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

Legend
 The number mentioned is **Electron affinity** in kJ/mol (rounded)
 * Denotes elements that are expected to have electron affinities close to zero on quantum mechanical grounds
 For the equivalent value in eV, see: [Electron affinity \(data page\)](#)

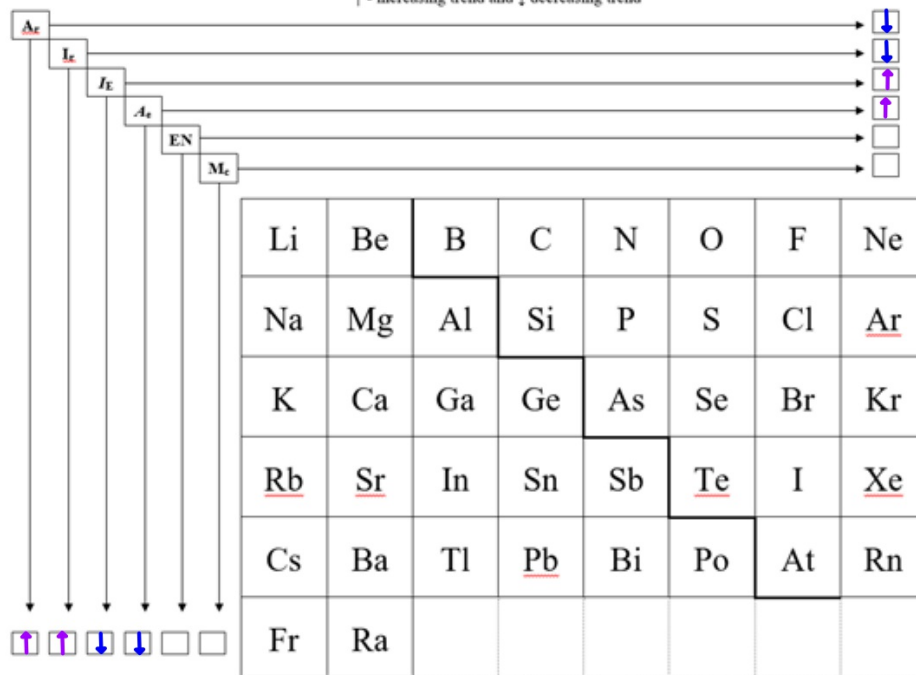


Periodic Trends - Electron Affinity (A_e)

**Periodicity
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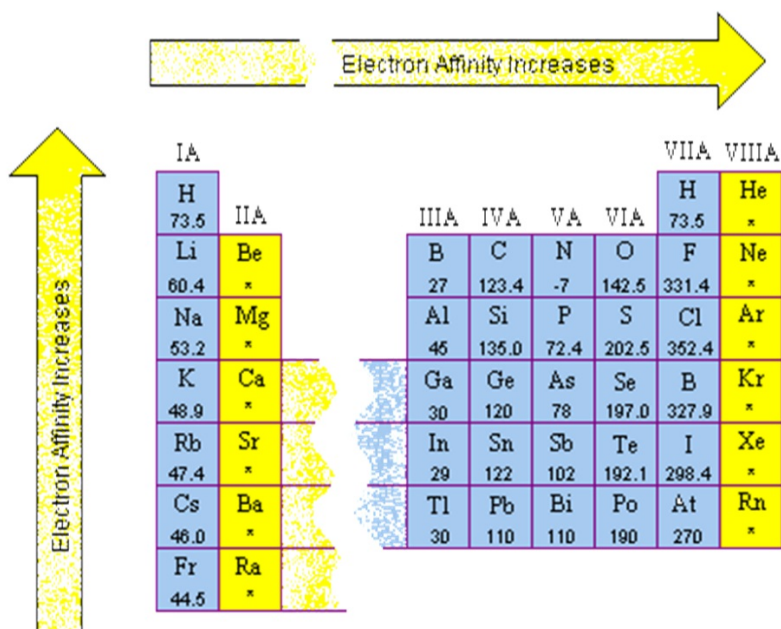
Periodicity **Topic#6** Trends Study Aide

A_r - atomic radius, I_r - ionic radius, I_E - ionization energy, A_e - electron affinity, EN - electronegativity, and M_c - metallic character
 ↑ - increasing trend and ↓ decreasing trend



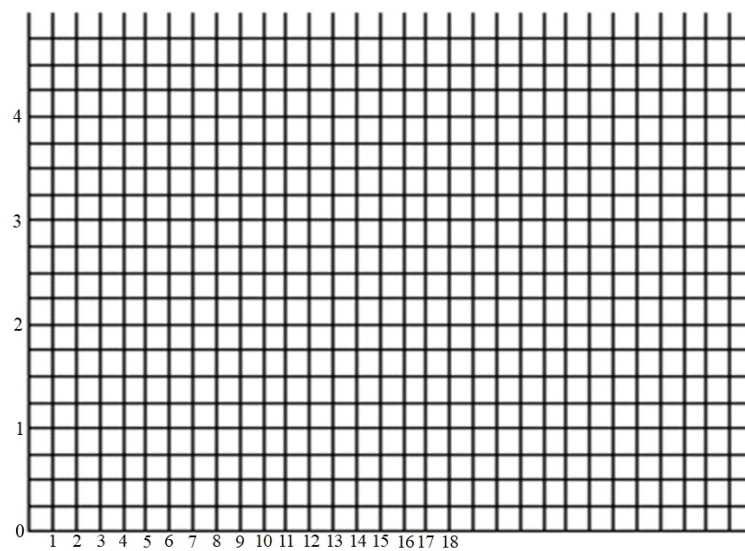
Periodic Trends - Electron Affinity (A_e)

**Periodicity
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Periodic Trends - Electronegativity (EN)

Element	EN	Element	EN
Li	1.0	Na	0.9
Be	1.5	Mg	1.2
B	2.0	Al	1.5
C	2.5	Si	1.8
N	3.0	P	2.1
O	3.5	S	2.5
F	4.0	Cl	3.0

**Periodicity
Topic#6**

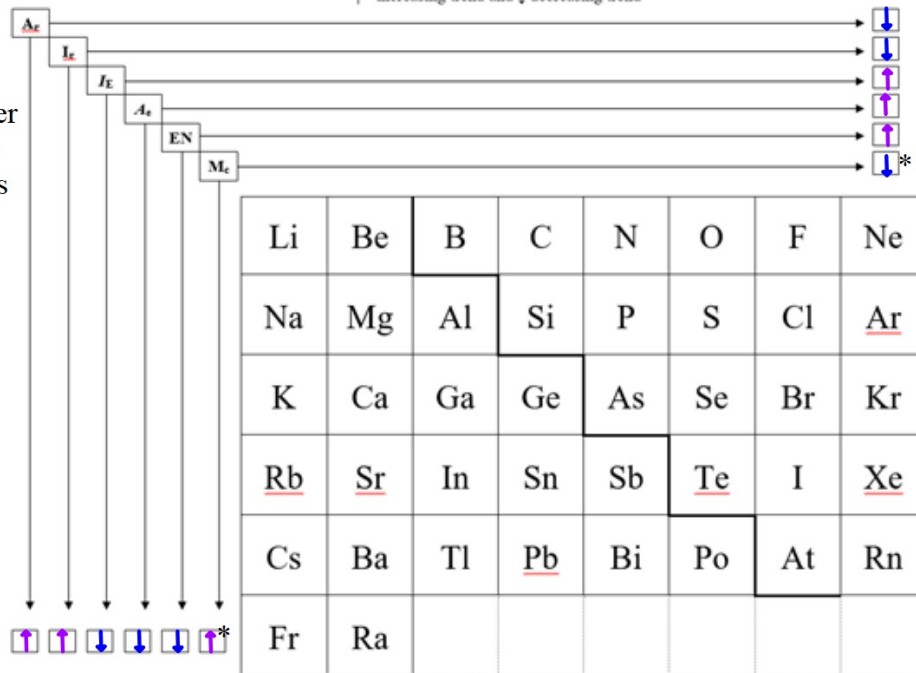
Periodicity Topic#6

Periodic Trends - Electronegativity (EN)

Periodicity Topic#6 Trends Study Aide

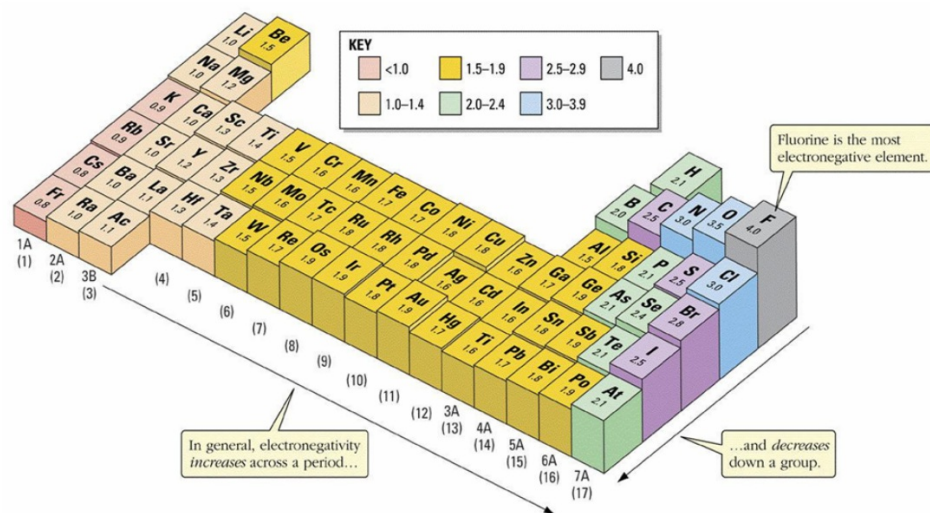
A_r – atomic radius, I_r – ionic radius, I_E – ionization energy, A_e – electron affinity, EN – electronegativity, and M_c – metallic character
 ↑ - increasing trend and ↓ decreasing trend

*Metallic Character
 - increases down a
 group and decreases
 across a period



Periodicity
Topic#6

Periodic Trends - Electronegativity (EN)



Electronegativity

5. Among the elements Ga, Br, and Ca, which has the highest electronegativity? Explain why in terms of periodic trends.

Periodicity Topic#6

Periodic Trends - Electronegativity (EN)

H																	He					
Li	Be											B	C	N	O	F	Ne					
Na	Mg											Al	Si	P	S	Cl	Ar					
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr					
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe					
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn					
Fr	Ra	Ac	Unq	Unp	Unh	Uns	Uno	Une														
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									

6. Consider the five hypothetical main-group elements E, G, J, L, and M with the outer electron configurations shown below

$$E = 2s^2 2p^5$$

$$G = 4d^{10} 5s^2 5p^5$$

$$J = 2s^2 2p^3$$

$$L = 5d^{10} 6s^2 6p^5$$

$$M = 2s^2 2p^4$$

- Identify the block location of each element. Then determine which elements are in the same period and which are in the same group.
- Which element would you expect to have the highest electron affinity? To form a 1- ion? Highest electronegativity?
- Compare the ionic radius of the typical ion formed by the element G with the radius of its neutral atom.
- Which element(s) contain seven valence electrons?

Periodicity Topic#6

Valence Electrons

- outer electrons located in ONLY the s and p type orbitals.
- For example,
 - Mg has 2 valence electrons, $3s^2$
 - Thallium (Tl) has 3 valence electrons, $6s^26p^1$
- To determine the valence electrons of an element, go to the row it is in, this is n , then go to its group, this is the sum of the powers on the s and p . s can only have a maximum of 2 and p has a maximum of 6.
 - For elements in the d -block, their valence electrons are ALWAYS ns^2 .
 - For example, zirconium (Zr) has 2 valence electrons, $5s^2$.
- Elements in group 18 (except He) have eight valence electrons (ns^2np^6). This is called the octet rule. This FULL outer energy level lends itself to stability.

Periodic Table of the Elements

Symbol		Name		Atomic Mass	
1	H	1	Hydrogen	1.008	
2	He	2	Helium	4.003	
3	Li	3	Lithium	6.941	
4	Be	4	Beryllium	9.012	
5	B	5	Boron	10.81	
6	C	6	Carbon	12.011	
7	N	7	Nitrogen	14.007	
8	O	8	Oxygen	15.999	
9	F	9	Fluorine	18.998	
10	Ne	10	Neon	20.180	
11	Na	11	Sodium	22.990	
12	Mg	12	Magnesium	24.305	
13	Al	13	Aluminum	26.982	
14	Si	14	Silicon	28.086	
15	P	15	Phosphorus	30.974	
16	S	16	Sulfur	32.065	
17	Cl	17	Chlorine	35.453	
18	Ar	18	Argon	39.948	
19	K	19	Potassium	39.098	
20	Ca	20	Calcium	40.078	
21	Sc	21	Scandium	44.956	
22	Ti	22	Titanium	47.867	
23	V	23	Vanadium	50.942	
24	Cr	24	Chromium	51.996	
25	Mn	25	Manganese	54.938	
26	Fe	26	Iron	55.845	
27	Co	27	Cobalt	58.933	
28	Ni	28	Nickel	58.693	
29	Cu	29	Copper	63.546	
30	Zn	30	Zinc	65.38	
31	Ga	31	Gallium	69.723	
32	Ge	32	Germanium	72.631	
33	As	33	Arsenic	74.922	
34	Se	34	Selenium	78.96	
35	Br	35	Bromine	79.904	
36	Kr	36	Krypton	83.798	
37	Rb	37	Rubidium	85.468	
38	Sr	38	Strontium	87.62	
39	Y	39	Yttrium	88.906	
40	Zr	40	Zirconium	91.224	
41	Nb	41	Niobium	92.906	
42	Mo	42	Molybdenum	95.94	
43	Tc	43	Technetium	98.907	
44	Ru	44	Ruthenium	101.07	
45	Rh	45	Rhodium	102.905	
46	Pd	46	Palladium	106.42	
47	Ag	47	Silver	107.868	
48	Cd	48	Cadmium	112.411	
49	In	49	Indium	114.818	
50	Sn	50	Tin	118.71	
51	Sb	51	Antimony	121.757	
52	Te	52	Tellurium	127.6	
53	I	53	Iodine	126.905	
54	Xe	54	Xenon	131.294	
55	Cs	55	Cesium	132.905	
56	Ba	56	Barium	137.327	
57	La	57	Lanthanum	138.905	
58	Ce	58	Cerium	140.116	
59	Pr	59	Praseodymium	140.908	
60	Nd	60	Niodymium	144.242	
61	Pm	61	Promethium	144.913	
62	Sm	62	Samarium	150.36	
63	Eu	63	Europium	151.964	
64	Gd	64	Gadolinium	157.25	
65	Tb	65	Terbium	158.925	
66	Dy	66	Dysprosium	162.500	
67	Ho	67	Holmium	164.930	
68	Er	68	Erbium	167.259	
69	Tm	69	Thulium	168.934	
70	Yb	70	Ytterbium	173.054	
71	Lu	71	Lutetium	174.967	
72	Hf	72	Hafnium	178.49	
73	Ta	73	Tantalum	180.948	
74	W	74	Tungsten	183.84	
75	Re	75	Rhenium	186.207	
76	Os	76	Osmium	190.23	
77	Ir	77	Iridium	192.222	
78	Pt	78	Platinum	195.085	
79	Au	79	Gold	196.967	
80	Hg	80	Mercury	200.592	
81	Tl	81	Thallium	204.383	
82	Pb	82	Lead	207.2	
83	Bi	83	Bismuth	208.980	
84	Po	84	Polonium	209	
85	At	85	Astatine	210	
86	Rn	86	Radon	222	
87	Fr	87	Francium	223	
88	Ra	88	Radium	226	
89-103	Lanthanide Series				
104	Rf	104	Rutherfordium	[261]	
105	Db	105	Dubnium	[262]	
106	Sg	106	Seaborgium	[266]	
107	Bh	107	Berkelium	[267]	
108	Hs	108	Hassium	[269]	
109	Mt	109	Moscovium	[288]	
110	Ds	110	Darmstadtium	[285]	
111	Rg	111	Roentgenium	[282]	
112	Cn	112	Copernicium	[285]	
113	Uut	113	Ununtrium	[284]	
114	Fu	114	Flerovium	[289]	
115	Uup	115	Ununpentium	[288]	
116	Lv	116	Livermorium	[293]	
117	Uus	117	Ununseptium	[294]	
118	Uuo	118	Ununoctium	[294]	

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Periodicity Topic#6

Electron Dot Diagrams

- A diagram using the symbol of an atom and its valence electrons (outer s and p electrons)
- For example, Be (beryllium) has 2 valence electrons ($2s^2$), so its electron dot diagram is $\text{Be}:$

Valence electrons/Electron Dot Diagram

7. Determine the valence electrons and electron dot diagram for the following atoms:

a. K (Group ___) e. Si (Group ___)

b. In (Group ___) f. Os (Group ___)

c. Te (Group ___) g. Xe (Group ___)

d. I (Group ___)

Periodic Table of the Elements

Valence electron configurations are indicated by arrows pointing to groups:

- ns^1 (Group 1)
- ns^2 (Group 2)
- ns^2np^1 (Group 13)
- ns^2np^2 (Group 14)
- ns^2np^3 (Group 15)
- ns^2np^4 (Group 16)
- ns^2np^5 (Group 17)
- ns^2np^6 (Group 18)

Legend:

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Semimetal
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide