

Chapter 8: Periodic Trends

Atoms gain, lose, or share electrons to obtain a noble-gas electron configuration.

Noble Gas Electron Configuration = ns^2np^6 = an octet, 8 electrons in the valence shell (highest n value). This is a very stable arrangement because it allows the greatest number of electrons to experience the greatest possible effective nuclear charge (Z_{eff}).

Electron Configurations of Ions

Anions: Add electrons to outermost shell of atom

Examples:

N atom = $1s^22s^22p^3$ N ³⁻ ion = $1s^22s^22p^6$ = [Ne]	O atom = $1s^22s^22p^4$ O ²⁻ ion = $1s^22s^22p^6$ = [Ne]	F atom = $1s^22s^22p^5$ F ⁻ ion = $1s^22s^22p^6$ = [Ne]
P atom = [Ne] $3s^23p^3$ P ³⁻ ion = [Ne] $3s^23p^6$ = [Ar]	S atom = [Ne] $3s^23p^4$ S ²⁻ ion = [Ne] $3s^23p^6$ = [Ar]	Cl atom = [Ne] $3s^23p^5$ Cl ⁻ ion = [Ne] $3s^23p^6$ = [Ar]
Atoms in Group 5A have 5 valence electrons and gain 3 more electrons to get octet. These anions have -3 charge.	Atoms in Group 6A have 6 valence electrons and gain 2 more electrons to get octet. These anions have -2 charge.	Atoms in Group 7A have 7 valence electrons and gain 1 more electron to get octet. These anions have -1 charge.

Cations

Main Group Elements (Representative elements. i.e., not the transition metals)

Remove electrons from outermost shell (highest value of n)

Examples

Na atom = [Ne] $3s^1$ Na ⁺ ion = [Ne]	Mg atom = [Ne] $3s^2$ Mg ²⁺ ion = [Ne]	Al atom = [Ne] $3s^23p^1$ Al ³⁺ ion = [Ne]
K atom = [Ar] $4s^1$ K ⁺ ion = [Ar]	Ca atom = [Ar] $4s^2$ Ca ²⁺ ion = [Ar]	
Atoms in Group 1A have 1 valence electron and lose 1 electron to gain an octet. These cations have +1 charge.	Atoms in Group 2A have 2 valence electrons and lose 2 electron to gain an octet. These cations have +2 charge.	Atoms in Group 2A have 2 valence electron and lose 2 electron to gain an octet. These cations have +2 charge.

Transition Metal Cations

Electrons are removed from ns subshell before the (n-1)d subshell

Fe atom = [Ar] $4s^23d^6$	Fe ²⁺ ion = [Ar] $3d^6$	Fe ³⁺ ion = [Ar] $3d^5$
	The 4s electrons have been removed.	The 4s electrons and 1 of the 3d electrons have been removed.

Isoelectronic Series (Isoelectronic = same number of electrons)

All of the ions below have 10 electrons and are thus isoelectronic with Ne.

	O ²⁻	F ⁻	Na ⁺	Mg ²⁺
Radius (pm)	140	133	98	78
Z	8	9	11	12
# of electrons	10	10	10	10

The radius gets smaller as the number of protons increases because the 10 electrons are pulled closer to the nucleus by the greater charge on the nucleus.

Periodic Table Trends (how properties vary for Main Group Elements as you move across the periodic table from left to right in a row, or down a column).

Atomic Radius (depends on the Z_{eff} felt by the outermost electrons)

Across a row (left to right): Decreases because the charge of the nucleus is getting larger and electrons in the same shell (same value of n) don't shield each other much.

Down a column: Increases because the value of n is increasing and electrons in lower n shell shield electrons in the higher n shell.

Ionic Radius

Cations are smaller than the atoms they are derived from. Anions are larger than the atoms they are derived from.

Ionization Energy (IE) = energy required to remove an electron from an atom in its ground state in the gas phase. First IE = energy required to remove first electron. Second IE = energy required to remove 2nd electron, etc.

First IE:

Across a row (left to right): Increases because atoms are getting smaller. Outermost electron is more tightly held by nucleus.

Down a column: Decreases because atoms are getting bigger. Outermost electron is less tightly held by nucleus.

Electron Affinity (EA) = negative of the energy change that occurs when an atom accepts an electron to form an anion (atom is in the ground state and the gas phase). In other words, larger EA means atom accepting electron to become anion is a favored process.

General periodic trends: Several exceptions exist, but, in general, EA increases as you go across a row from left to right and decreases as you go down a column. This also correlates with the size trend. It is more favorable to add an electron to a small atom than to a large atom because the added electron is closer to the nucleus and feels greater effect of the nuclear charge. Many exceptions exist because some atoms don't gain electrons to form anions so the value can't be measured and because some anions are unusually stable because they have a particularly stable electron configuration (such as a filled or half-filled subshell).

Metallic Character:

Metals tend to lose electrons to form cations. Non-metals tend to gain electrons to form anions.

Periodic Trend (we learned this early in the semester)

Across a row (left to right): metallic character is decreasing.

Down a column: metallic character is increasing.

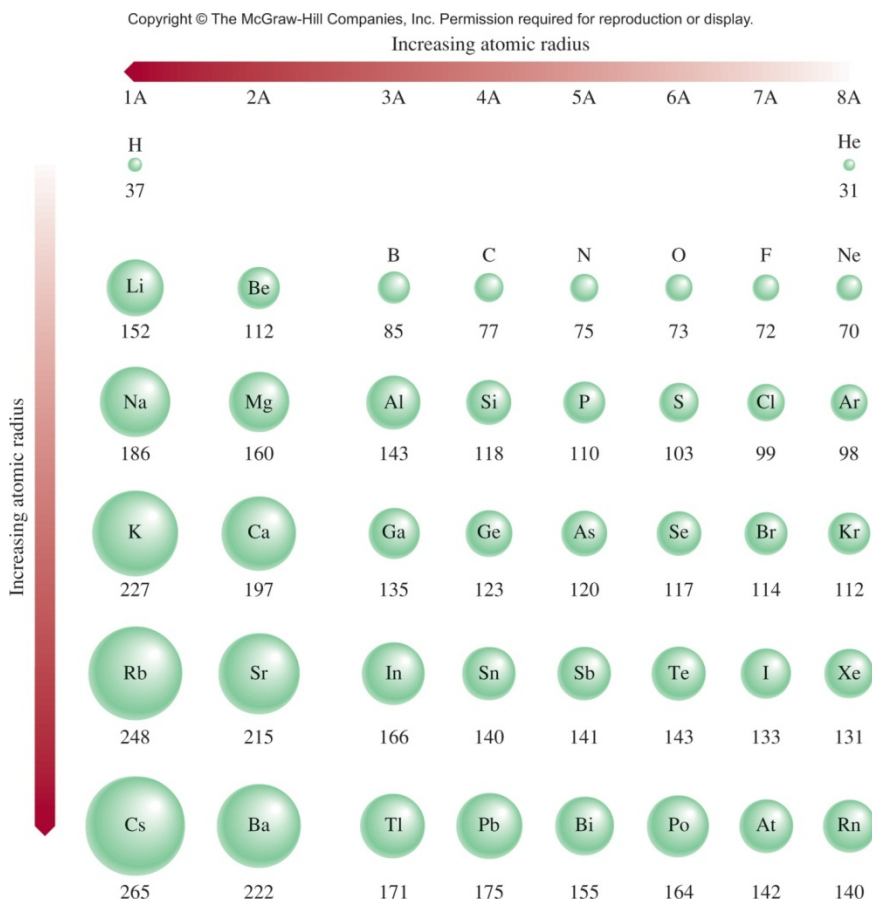
Summary Examples:

Atom	1 st IE	EA	Metallic Character
Cs	Very low: Easy to remove its outermost electron	Very Small: Wants to lose an electron, not gain one.	Very high.
F	Very high: Hard to remove its outermost electron	Very Large: Wants very much to gain an electron	Very Low.

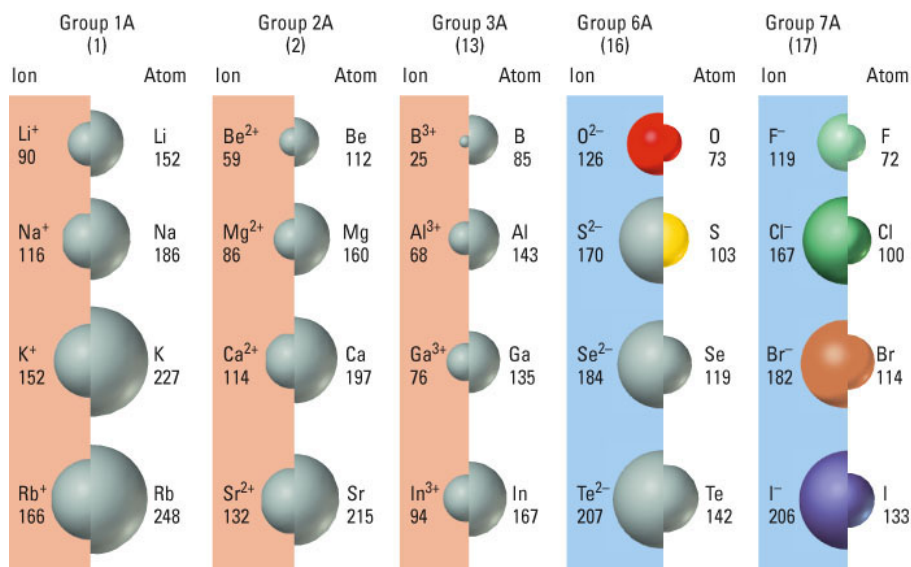
Periodic Trends

Figures from *Chemistry*, 11th Ed, Chang, Goldsby McGraw-Hill unless otherwise noted.

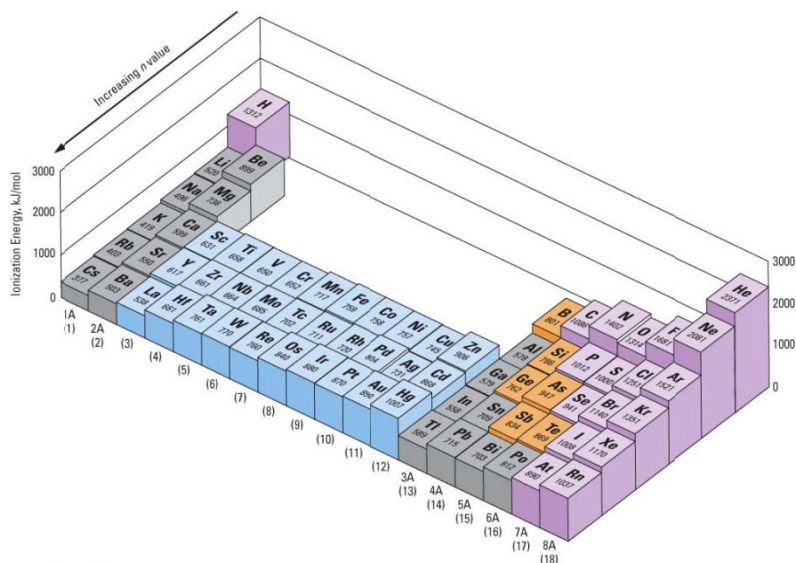
Atomic Radius



Ionic Radii (Figure from More, Stanitski, Jurs, *Chemistry: The Molecular Science*, 3rd Edition, Thomson.)



Ionization Energies (Figures from More, Stanitski, Jurs, *Chemistry: The Molecular Science*, 3rd Edition, Thomson.)



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Table 7.8 Ionization Energies Required to Remove Successive Electrons from Second-Period Atoms

Ionization Energy (10 ⁶ J/mol)	Li 1s ² 2s ¹	Be 1s ² 2s ²	B 1s ² 2s ² 2p ¹	C 1s ² 2s ² 2p ²	N 1s ² 2s ² 2p ³	O 1s ² 2s ² 2p ⁴	F 1s ² 2s ² 2p ⁵	Ne 1s ² 2s ² 2p ⁶
IE ₁	0.52	0.90	0.80	1.09	1.40	1.31	1.68	2.08
IE ₂	7.30	1.76	2.43	2.35	2.86	3.39	3.37	3.95
IE ₃	11.81	14.85	3.66	4.62	4.58	5.30	6.05	6.12
IE ₄		21.01	25.02	6.22	7.48	7.47	8.41	9.37
IE ₅			32.82	37.83	9.44	10.98	11.02	12.18
IE ₆				47.28	53.27	13.33	15.16	15.24
IE ₇					64.37	71.33	17.87	20.00
IE ₈		Core electrons				84.08	92.04	23.07
IE ₉							106.43	115.38
IE ₁₀								131.43

Note: In each of these elements the core electrons are those in the 1s orbital.

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Electron Affinities

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Table 8.3 Electron Affinities (kJ/mol) of Some Representative Elements and the Noble Gases*

1A	2A	3A	4A	5A	6A	7A	8A
H							He
73							< 0
Li	Be	B	C	N	O	F	Ne
60	≤ 0	27	122	0	141	328	< 0
Na	Mg	Al	Si	P	S	Cl	Ar
53	≤ 0	44	134	72	200	349	< 0
K	Ca	Ga	Ge	As	Se	Br	Kr
48	2.4	29	118	77	195	325	< 0
Rb	Sr	In	Sn	Sb	Te	I	Xe
47	4.7	29	121	101	190	295	< 0
Cs	Ba	Tl	Pb	Bi	Po	At	Rn
45	14	30	110	110	?	?	< 0

*The electron affinities of the noble gases, Be, and Mg have not been determined experimentally, but are believed to be close to zero or negative.