Announcements for Thursday, 26SEP2024

- Monday's lecture will be a review
- Week 4 Homework Assignments available on eLearning
  - Graded and Timed Quiz 4 – "Quantum" due **Monday, 30SEP2024, at 6:00 PM (EDT)**
- Practice Exam 1 on Canvas
  - located under "General Course information," "Practice Exams"
- Exam I is Tuesday, 01OCT2024, 7:45-9:05 **PM** (EDT)
  - Coverage: Chapters E-3.5; exam consists of 19 multiple-choice questions and open-ended questions; see "Other Resources" on Canvas for periodic table and formula sheet to be used on the exam
  - See Canvas announcement from Sep 25 about Exam Locations
- Exam I Calculator Policy
  - Scientific calculators and ***most*** graphing calculators are allowed
  - **TI-Nspire CX series & other calculators with *QWERTY* keyboards are NOT allowed**

ANY GENERAL QUESTIONS? Feel free to see me after class!

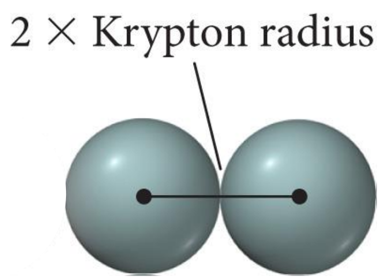
Try This On Your Own

Which of the following species has the MOST unpaired electrons?

Cu^{+}, N^{2-}, Kr, Mo, Mo^{+}, Fe^{3+}

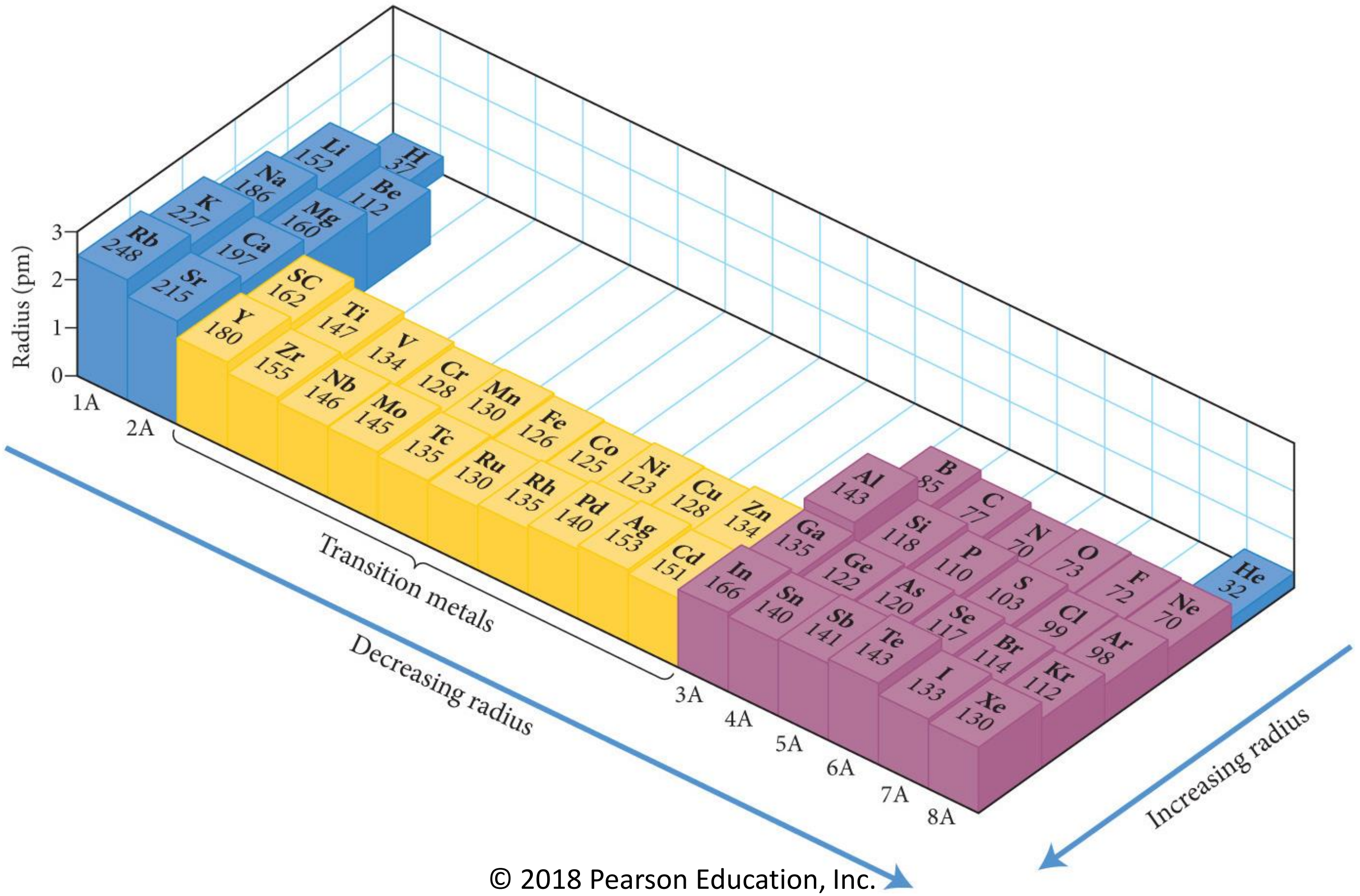
	parent atom		**ion**	**# unpaired e⁻s**
Cu^{+}	$[Ar]\ 4s^{1}\ 3d^{10}$	lose 1 e^{-}	$[Ar]\ 3d^{10}$	0
N^{2-}	$[He]\ 2s^{2}\ 2p^{3}$	gain 2 e^{-}s	$[He]\ 2s^{2}\ 2p^{5}$	1
Kr	$[Ar]\ 4s^{2}\ 3d^{10}\ 4p^{6}$			0
Mo	$[Kr]\ 5s^{1}\ 4d^{5}$			6
Mo^{+}	$[Kr]\ 5s^{1}\ 4d^{5}$	lose 1 e^{-}	$[Kr]\ 4d^{5}$	5
Fe^{3+}	$[Ar]\ 4s^{2}\ 3d^{6}$	lose 3 e^{-}s	$[Ar]\ 3d^{5}$	5

Periodic Trend: Atomic Radius



© 2018 Pearson Education, Inc.

- atomic radius ***decreases left-to-right*** across a period for Main group elements
  - atomic number/number of protons increases
  - amount of shielding does not increase significantly
  - **greater effective charge of the nucleus** pulls tightly on the electron cloud
  - *transition elements*: not much change in radius across a period
- atomic radius ***increases down*** a group for Main and Transition elements
  - increasingly higher principal energy levels occupied
  - as n increases, the electron's distance from the nucleus increases

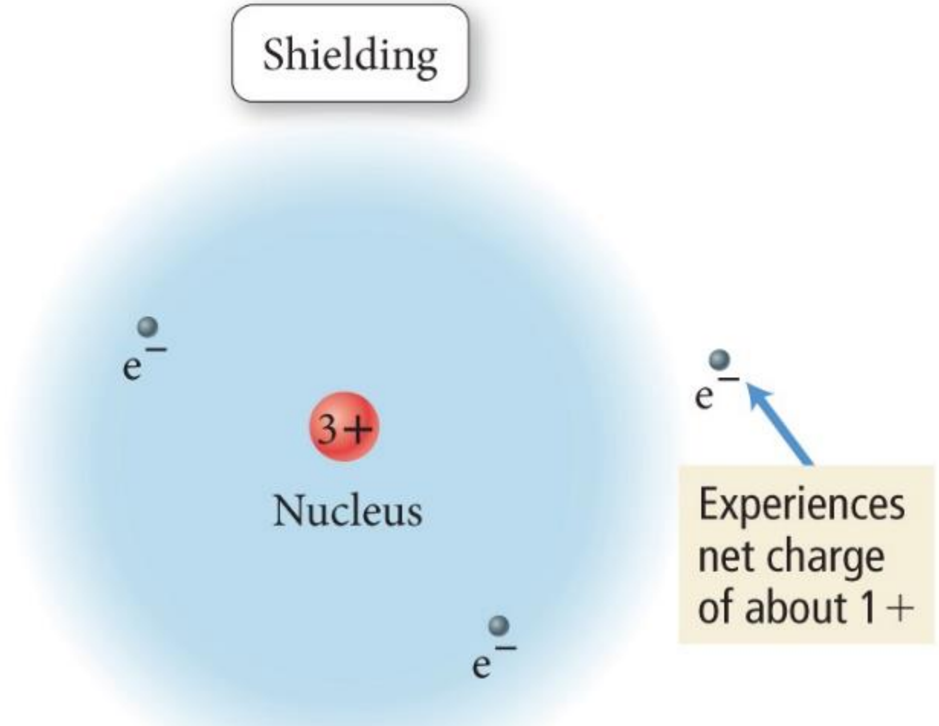


© 2018 Pearson Education, Inc.

HINT: MEMEORIZE He is the smallest atom and derive arrows

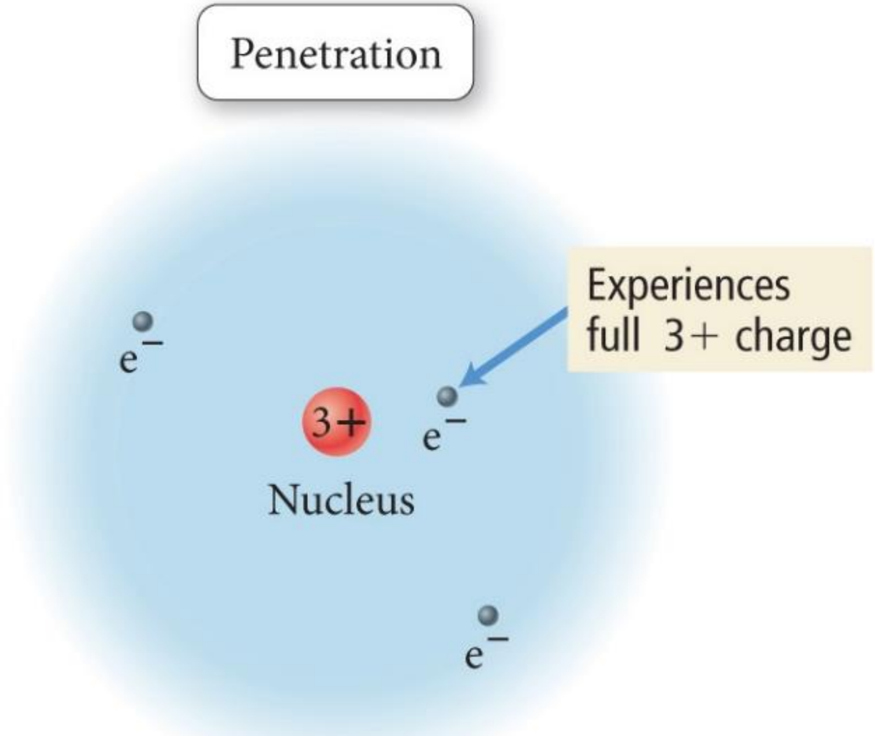
Effective Nuclear Charge (Z_{eff})

effective nuclear charge = the nuclear charge ***actually*** experienced by a given electron less the screening effect of other electrons within the atom



© 2018 Pearson Education, Inc.

- electrons experiencing **more shielding** will experience a **lesser effective nuclear charge** than electrons experiencing less shielding



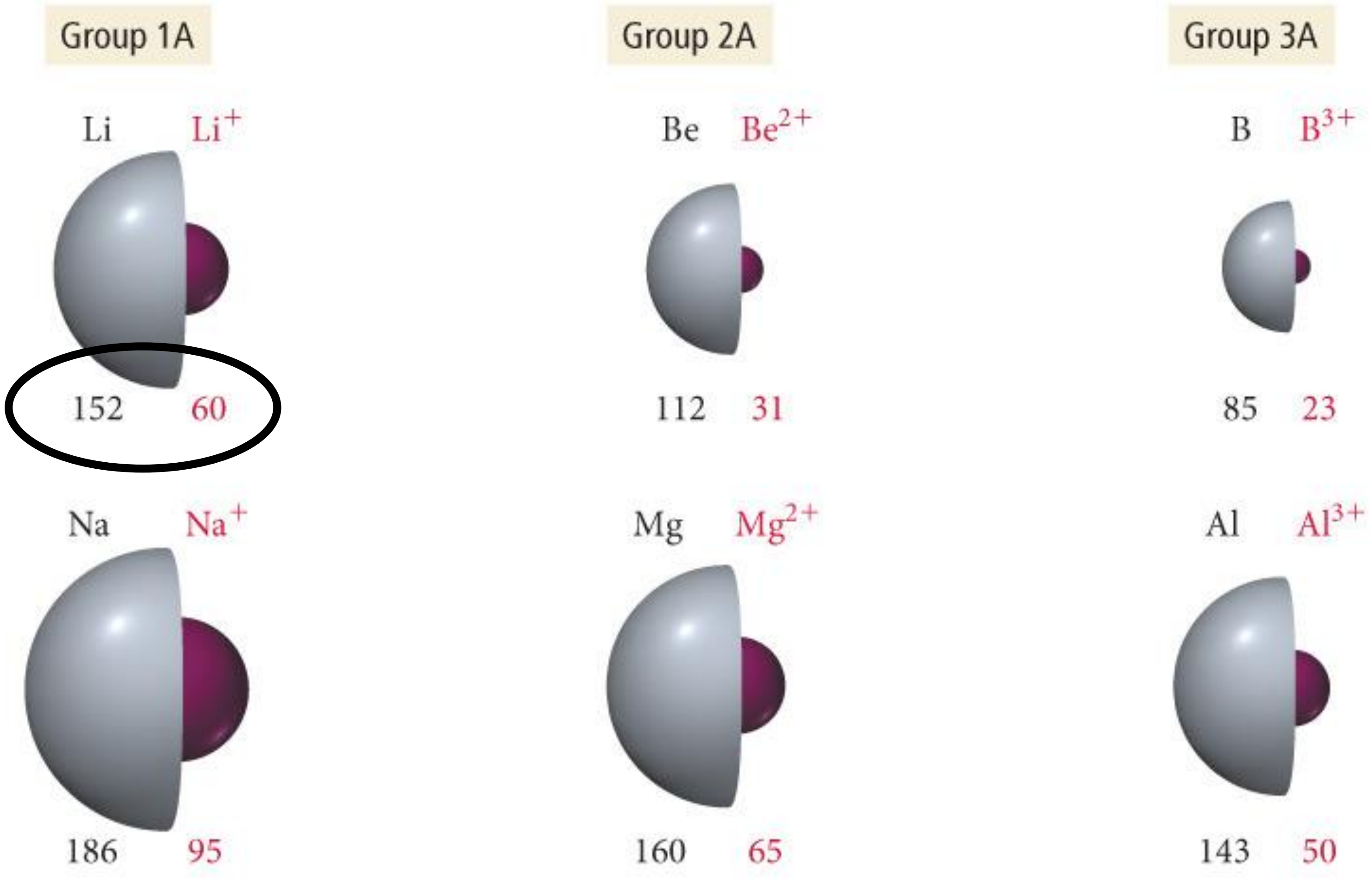
© 2018 Pearson Education, Inc.

- electrons that **penetrate closer** to the nucleus will experience a **greater effective nuclear charge** than electrons that do not penetrate as much

Ionic Radius vs. Atomic Radius

- **cations** have smaller radii than their parent atoms
  - same number of protons pulling on a smaller number of electrons
  - electron cloud pulled more tightly

radii of atoms and their **cations** (pm)

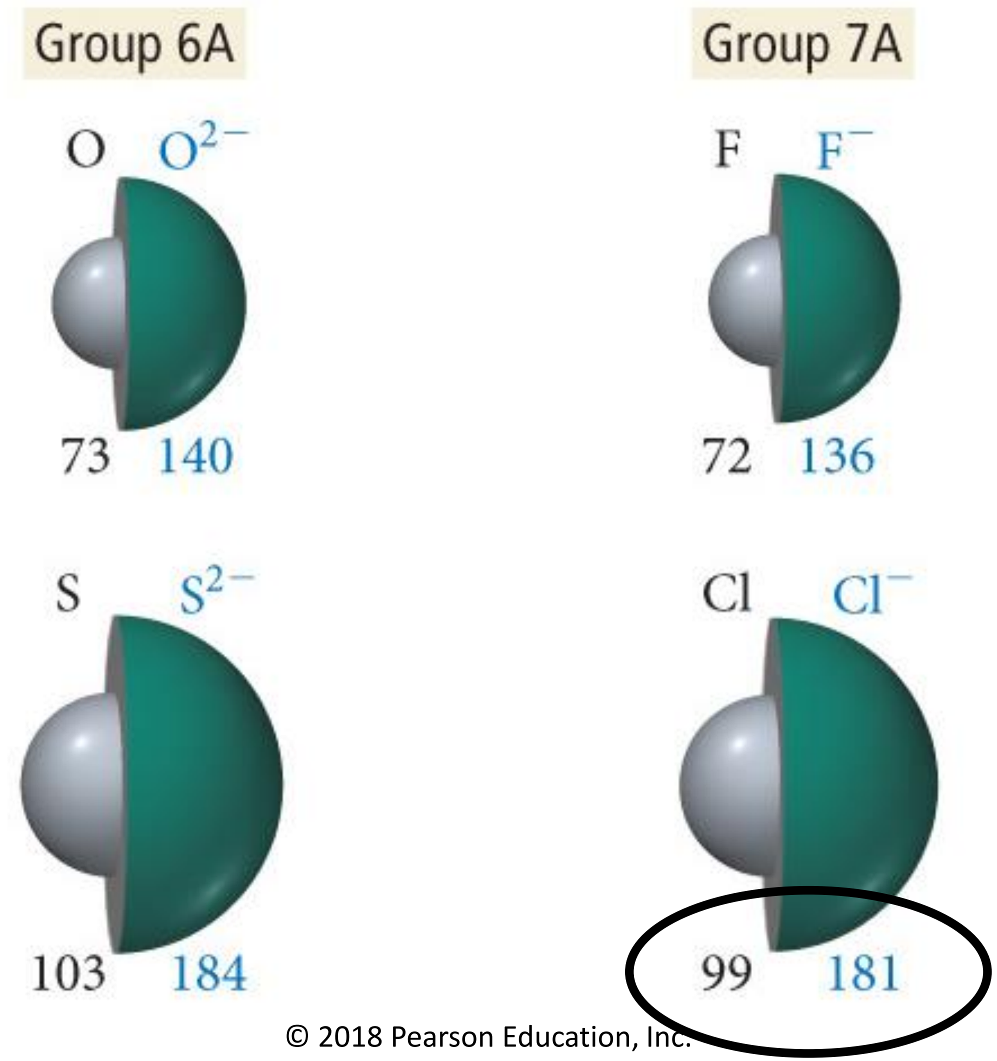


© 2018 Pearson Education, Inc.

Ionic Radius vs. Atomic Radius (continued)

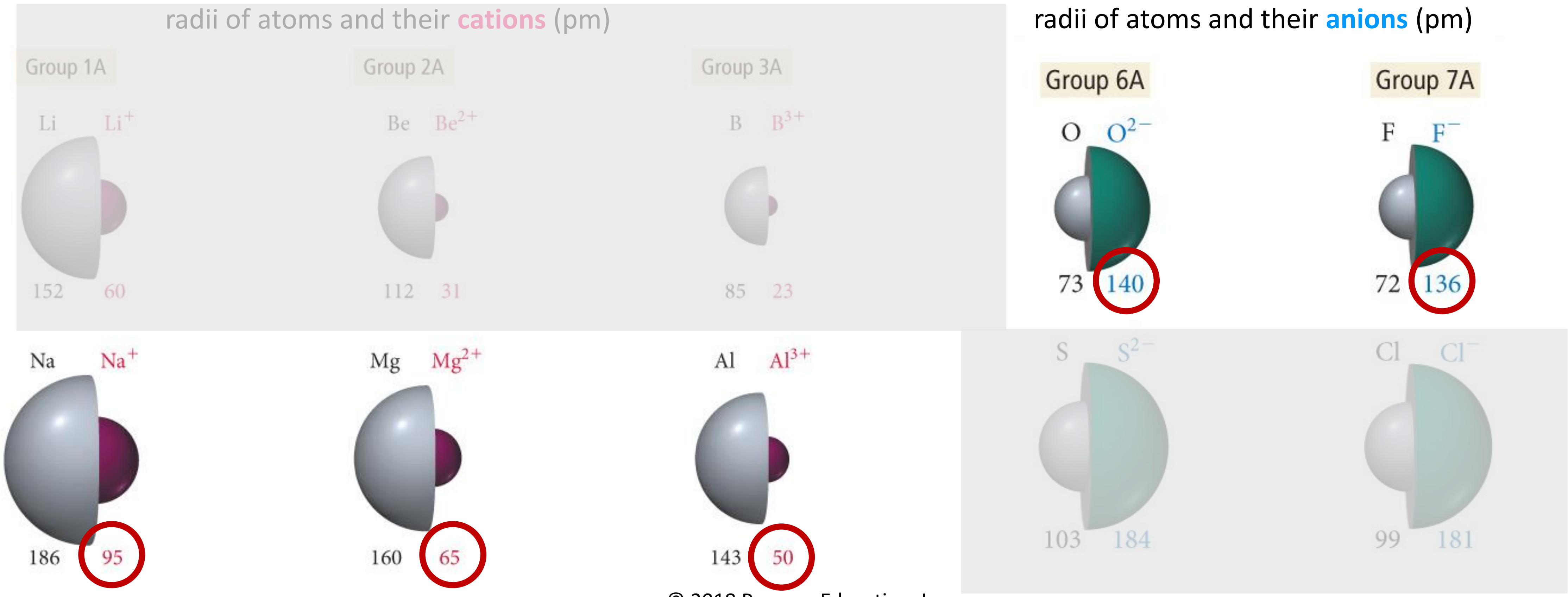
- **anions** have larger radii than their parent atoms
  - increased size due to increased electron repulsion

radii of atoms and their **anions** (pm)



© 2018 Pearson Education, Inc.

Isoelectronic Species



© 2018 Pearson Education, Inc.

- **isoelectronic species =** ions that have the same number of electrons (i.e., same electron configuration) but different numbers of protons
  - O^{2-}, F^{-}, Na^{+}, Mg^{2+}, Al^{3+} all have the electron configuration of [Ne]
  - the higher the value of Z, the smaller the radius

Try This On Your Own

Rank the following ions in order of *decreasing* radius:

Al^{3+}, F^{-}, I^{-}, Na^{+}, Te^{2-}

Periodic Trend: First Ionization Energy

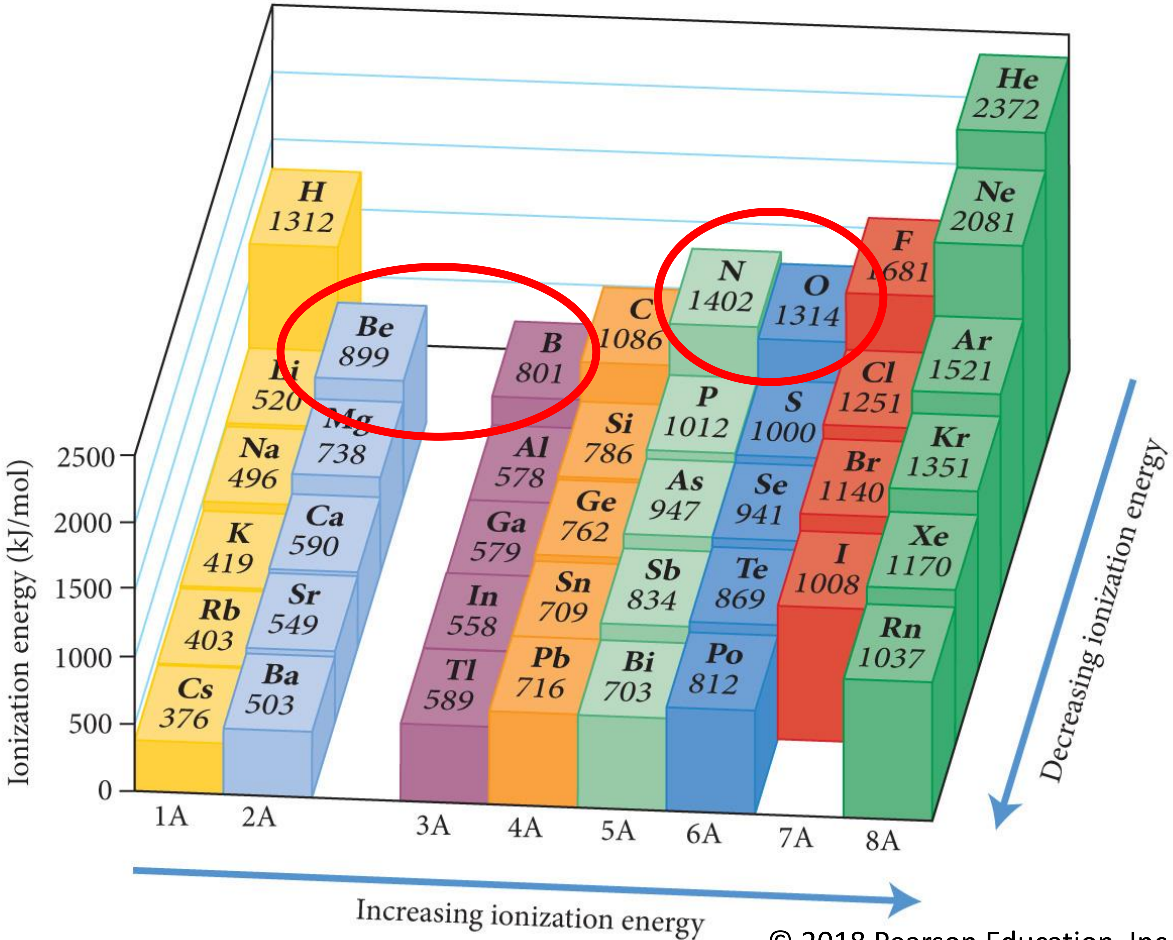
MEMORIZE: $X(g) \longrightarrow X^{+}(g) + 1\ e^{-}$

ionization energy = amount of energy required to remove an electron ***from an atom in the gas phase***

- first ionization energy ***increases left-to-right*** across a period for Main group elements
  - # protons increase yet amount of shielding does not increase significantly
  - **greater effective charge of the nucleus** pulls tightly on the electron cloud
  - harder to remove electrons

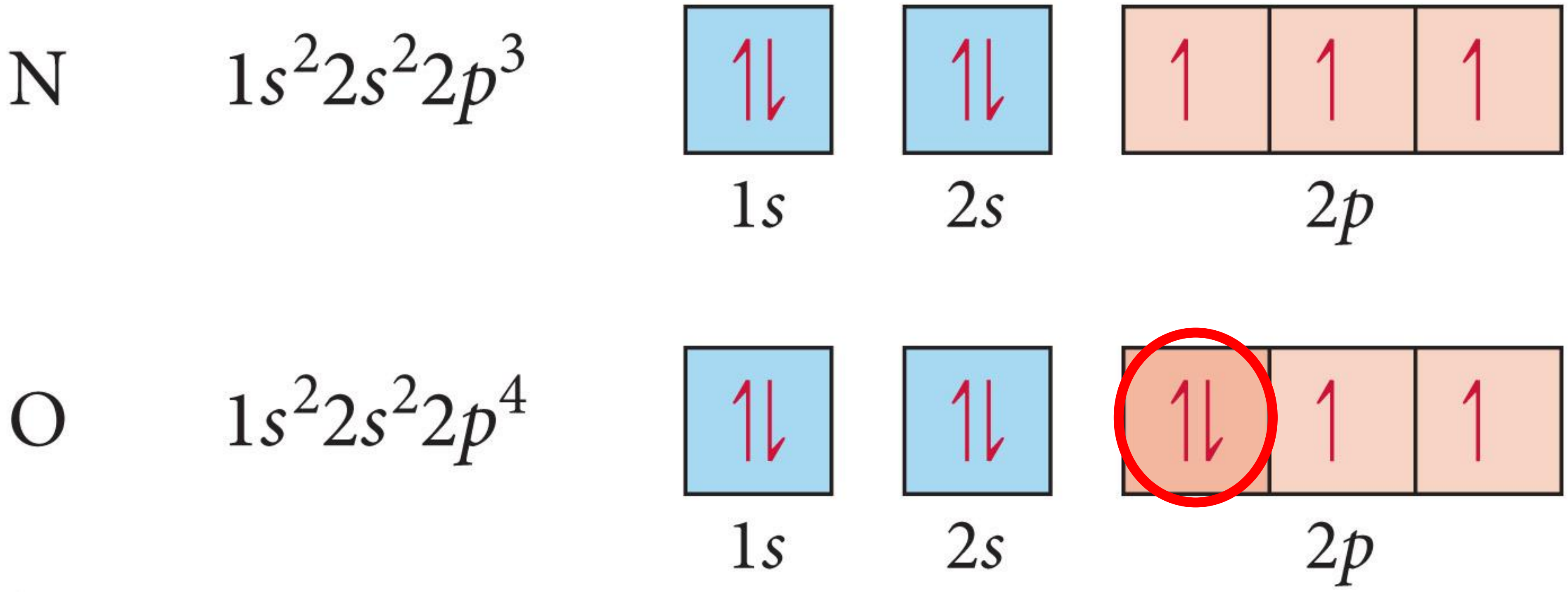
two anomalies to beware of

- Group 2A to 3A: e^{-} in p-orbital easier to remove than e^{-} in s-orbital
- Group 5A to Group 6A: due to relieving repulsions between two e^{-}s occupying the same orbital



© 2018 Pearson Education, Inc.

Group 5A/6A Anomaly in Ionization Energy



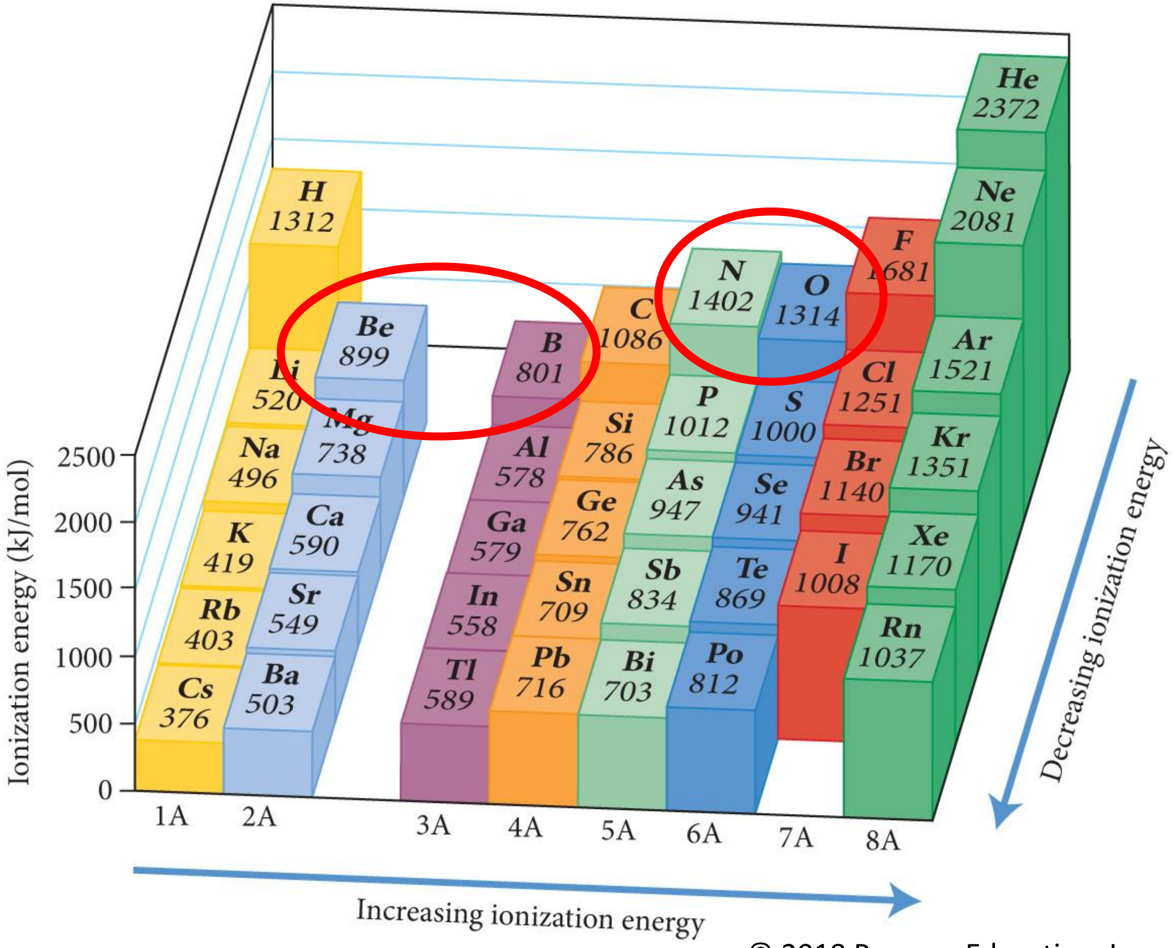
© 2018 Pearson Education, Inc.

- removal of an electron from oxygen relieves repulsions caused by two electrons occupying the same orbital
  - explains the anomalies in both ionization energy and electron affinity of Group 5A

Periodic Trend: First Ionization Energy (continued)

- first ionization energy ***decreases down*** a group
  - increasingly higher principal energy levels occupied
  - outer electrons are further away from the nucleus
  - not bound as tightly to the nucleus; easier to remove

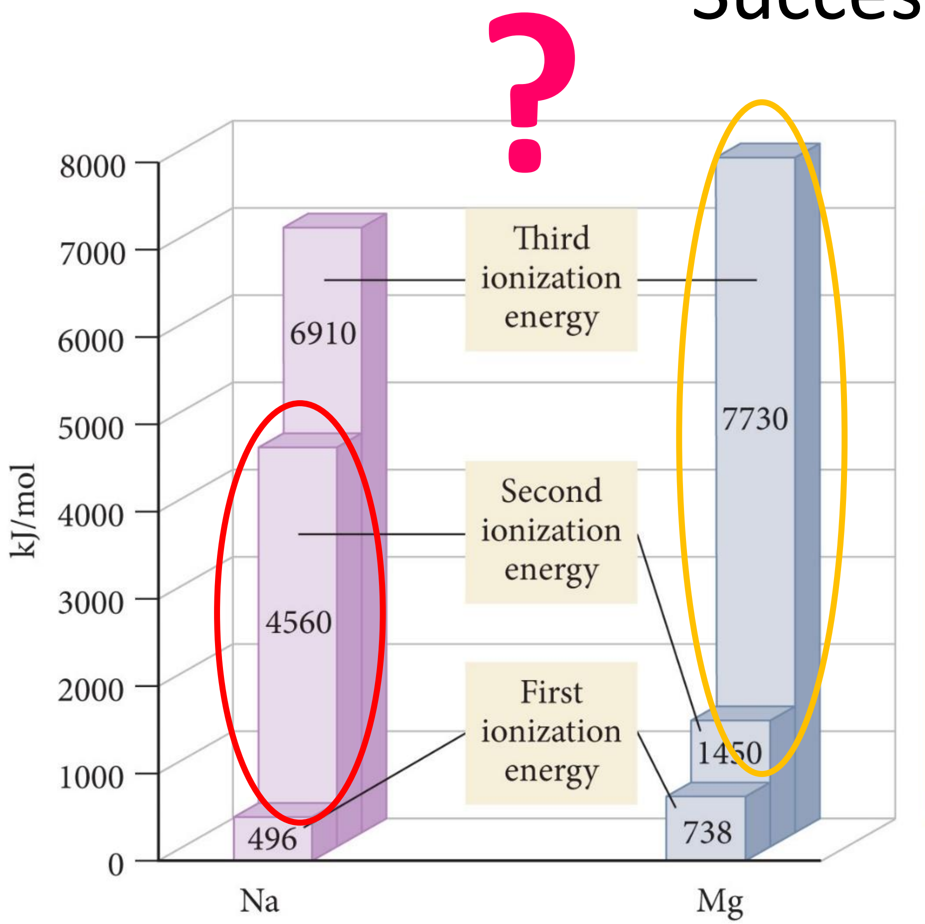
- **metals** tend to have **low ionization energies** and lose electrons to **become cations easily**
- **nonmetals** tend to have **high ionization energies** and resist losing electrons



© 2018 Pearson Education, Inc.

HINT: MEMEORIZE He is the hardest atom to ionize and derive trend

Successive Ionization Energies



© 2018 Pearson Education, Inc.

TABLE 3.1 Successive Values of Ionization Energies for the Elements Sodium through Argon (kJ/mol)

Element	IE_1	IE_2	IE_3	IE_4	IE_5	IE_6	IE_7
Na	496	4560					
Mg	738	1450	7730				
Al	578	1820	2750	11,600			
Si	786	1580	3230	4360	16,100		
P	1012	1900	2910	4960	6270	22,200	
S	1000	2250	3360	4560	7010	8500	27,100
Cl	1251	2300	3820	5160	6540	9460	11,000
Ar	1521	2670	3930	5770	7240	8780	12,000

Core electrons

© 2018 Pearson Education, Inc.

- it gets increasingly harder to remove successive electrons
  - the charge of the ion gets more positive after each removal
- a jump in ionization energy occurs upon removal of ***core electrons***

Try This On Your Own

- Rank the following species in order of increasing ionization energy:

$$Ba, Li, Be^{+}, Cs, Li^{+}$$

Try This On Your Own

- Identify the element from Period 2 has the following successive ionization energies:

  IE_1 = 1,086 kJ/mol

  IE_2 = 2,353 kJ/mol

  IE_3 = 4,621 kJ/mol

  IE_4 = 6,223 kJ/mol

  IE_5 = 37,831 kJ/mol

  IE_6 = 47,277 kJ/mol

Periodic Trend: Electron Affinity

MEMORIZE: $X(g) + 1\ e^- \longrightarrow X^-(g)$

electron affinity = amount of energy associated when an **atom <u>in the gas phase</u>** gains an electron

- electron affinity trend is not as well defined as other trends
  - Generally gets more negative across a period
  - **Group 2A, Group 5A, and Group 8A tend to have positive electron affinities**
  - **due to the stability of filled and half-filled subshells**
- nonmetals tend to have highly negative/exothermic electron affinities and favor gaining electrons to become anions
  - **halogens (Group 7A) have the most negative EAs**

Electron Affinities (kJ/mol)

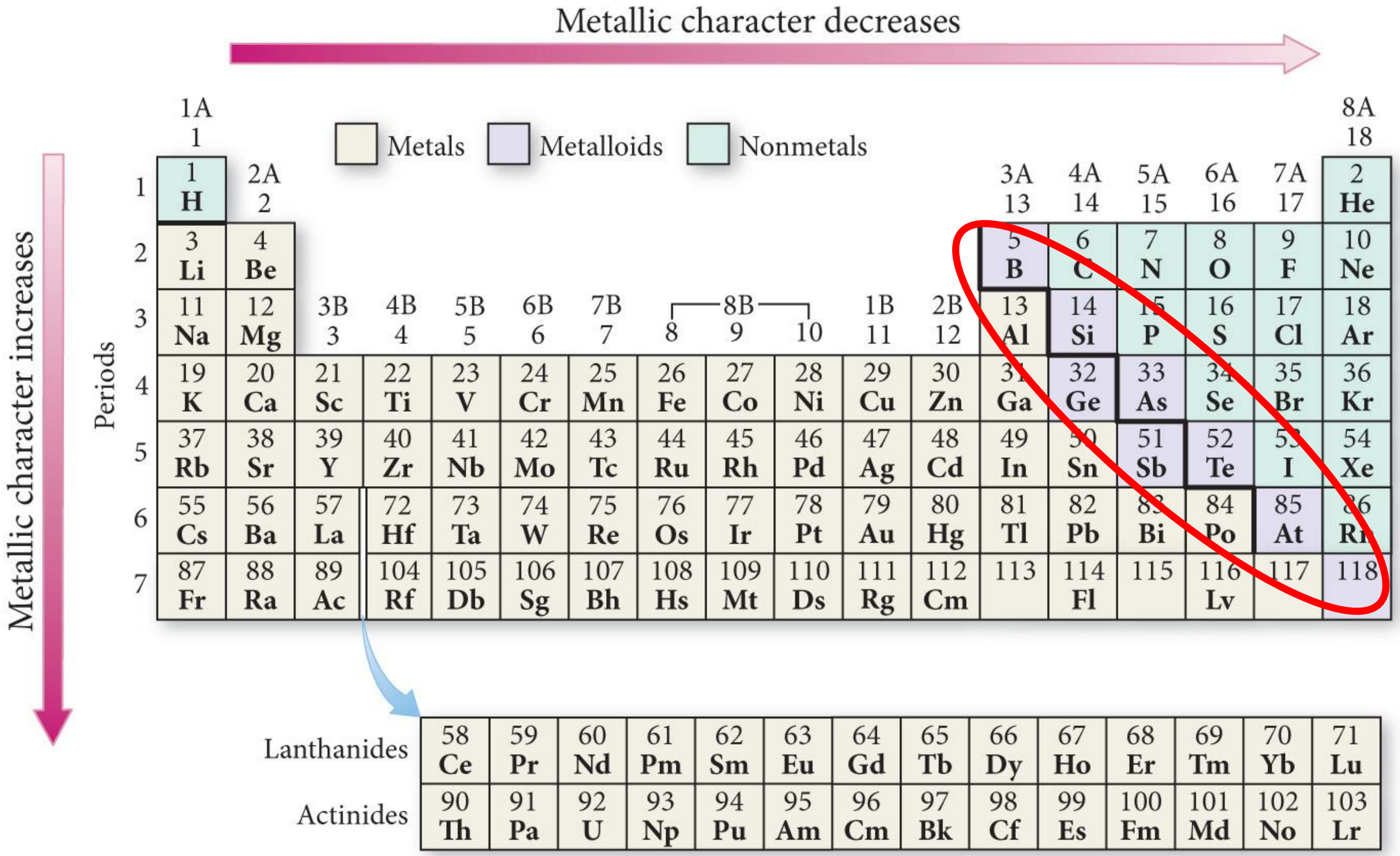
1A	2A	3A	4A	5A	6A	7A	8A
H −73							He >0
Li −60	Be >0	B −27	C −122	N >0	O −141	F −328	Ne >0
Na −53	Mg >0	Al −43	Si −134	P −72	S −200	Cl −349	Ar >0
K −48	Ca −2	Ga −30	Ge −119	As −78	Se −195	Br −325	Kr >0
Rb −47	Sr −5	In −30	Sn −107	Sb −103	Te −190	I −295	Xe >0

© 2018 Pearson Education, Inc.

- successive electron affinities typically are endothermic/require energy due to increased repulsion of adding electrons to something already bearing a negative charge

Periodic Trend: Metallic Character

- metallic character decreases left-to-right across a period
- metallic character increases down a group

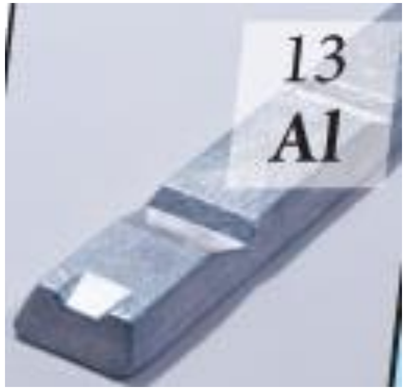


metals vs. nonmetals vs. metalloids on periodic table

© 2018 Pearson Education, Inc.

- metalloids are the dividing line
  - B, Si, Ge, As, Sb, Te, and At

Metals vs. Nonmetals: Properties



© 2018 Pearson Education, Inc.

© 2018 Pearson Education, Inc.

	metals	**nonmetals**
typical physical state	usually solids (except Hg)	solids, liquids, or gases
appearance	lustrous and shiny	dull
physical properties	high density malleable ductile conducts heat well conducts electricity well high melting and boiling points	low density brittle conducts heat poorly conducts electricity poorly low melting and boiling points
electron behavior	lose electrons easily to form cations	gain electrons easily to form anions