

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

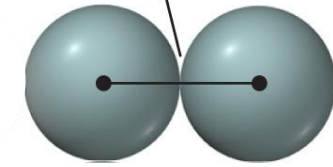
Which of the following species has the MOST unpaired electrons?

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

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

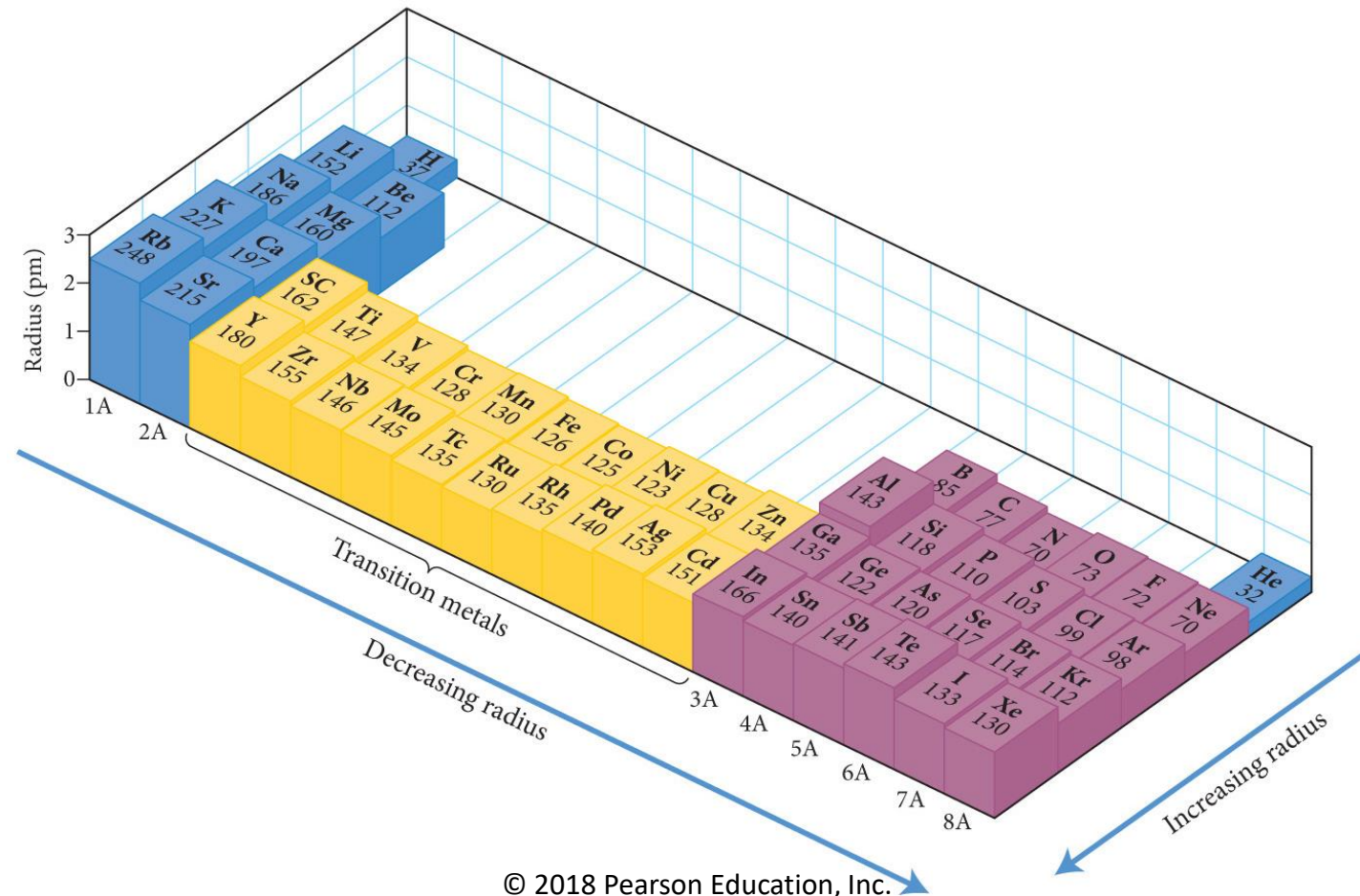
Periodic Trend: Atomic Radius

$2 \times \text{Krypton radius}$



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- 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



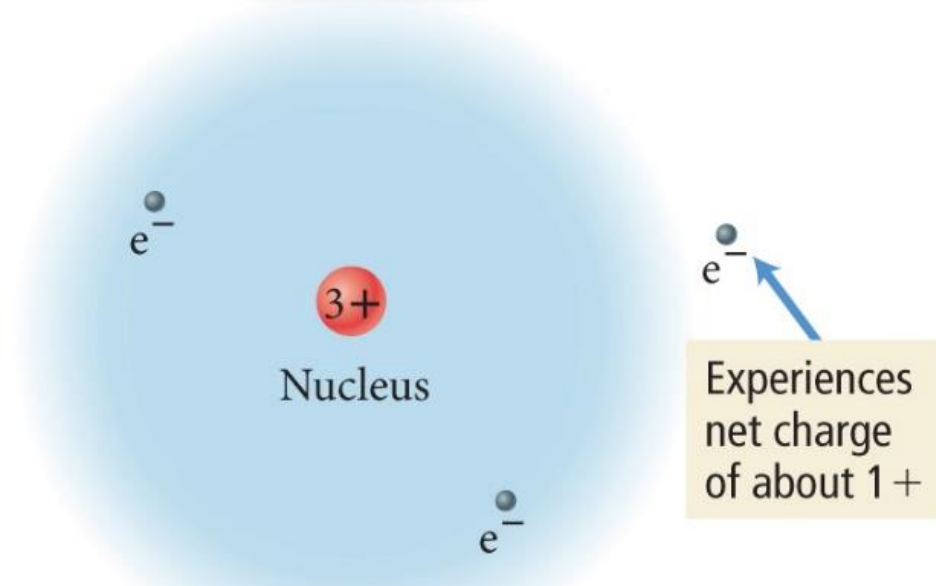
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HINT: MEMEORIZE He is the smallest atom and derive arrows

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

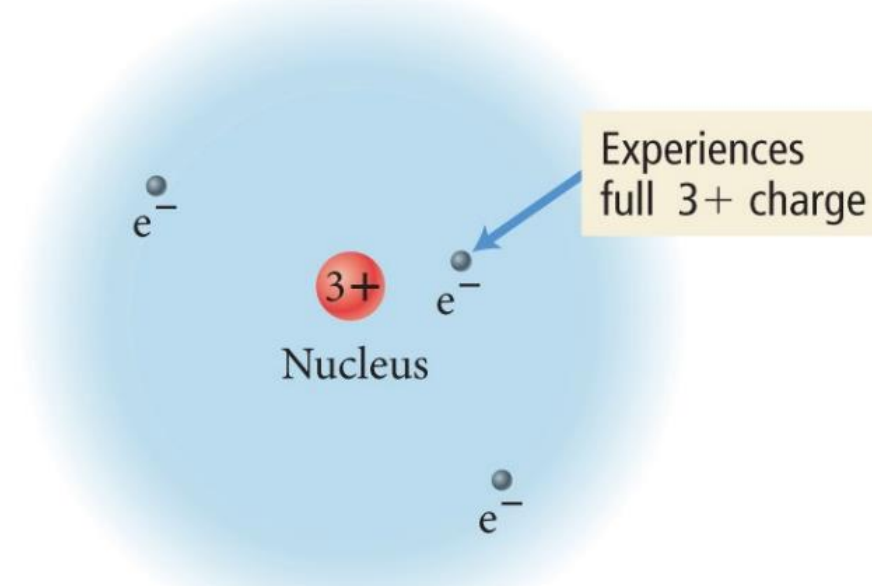
Shielding



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

Penetration



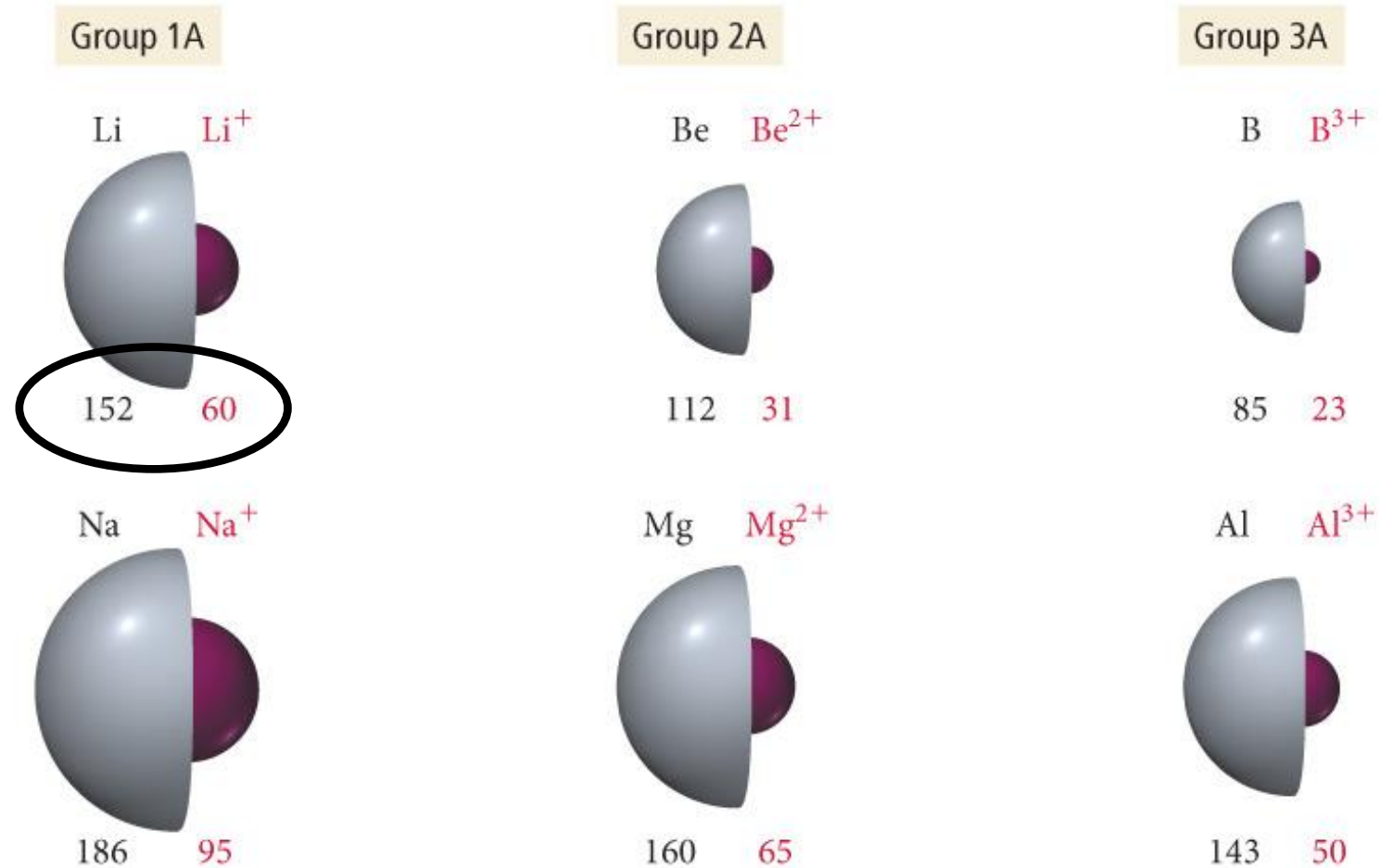
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- electrons that **penetrate closer** to the nucleus will experience a **greater effective nuclear charge** than electrons that do not penetrate as much

Ionic Radius vs. Atomic Radius

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

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



Ionic Radius vs. Atomic Radius (continued)

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

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

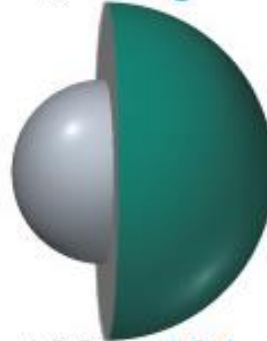
Group 6A

O O^{2-}



73 140

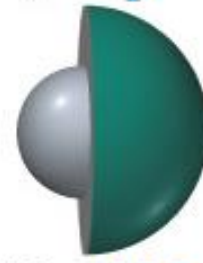
S S^{2-}



103 184

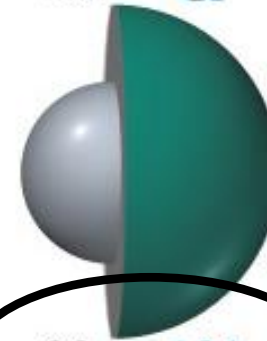
Group 7A

F F^-



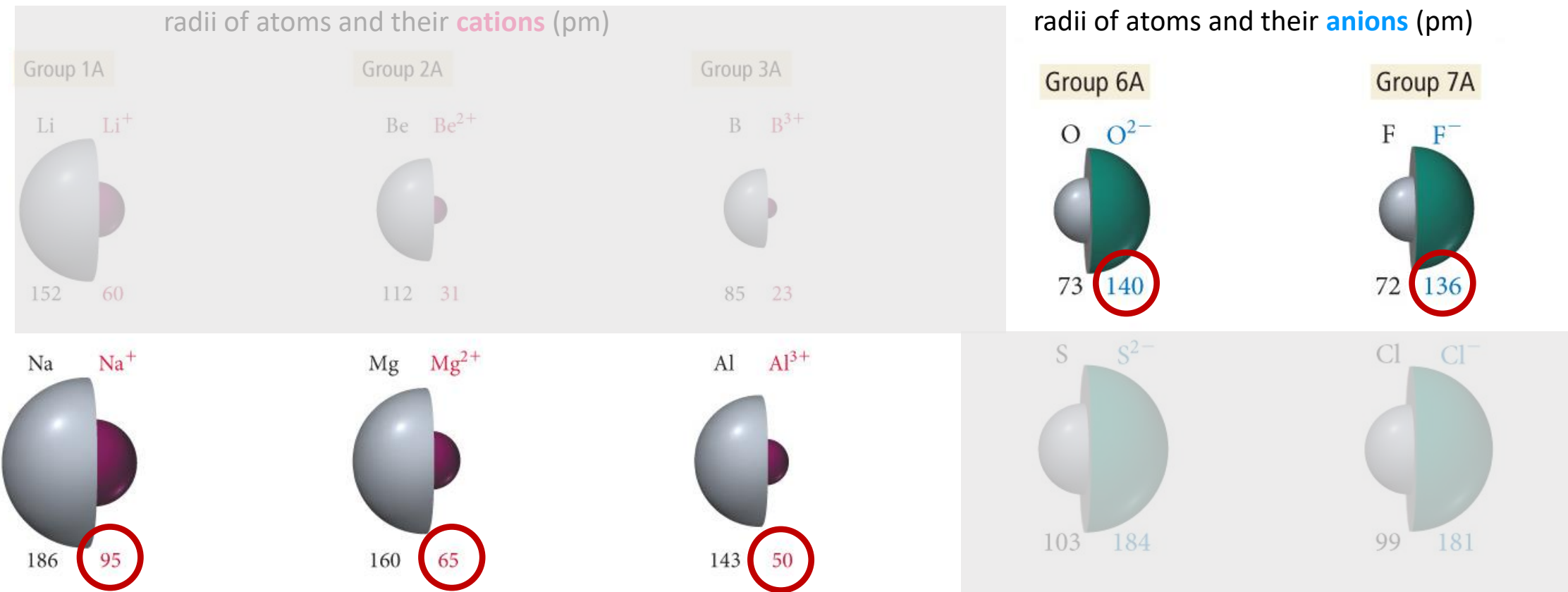
72 136

Cl Cl^-



99 181

Isoelectronic Species

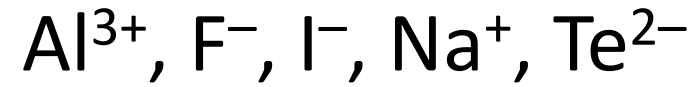


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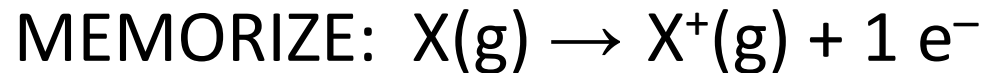
- **isoelectronic species** = ions that have the same number of electrons (i.e., same electron configuration) but different numbers of protons
 - O²⁻, F⁻, Na⁺, Mg²⁺, Al³⁺ all have the electron configuration of [Ne]
 - the higher the value of Z, the smaller the radius

Try This On Your Own

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

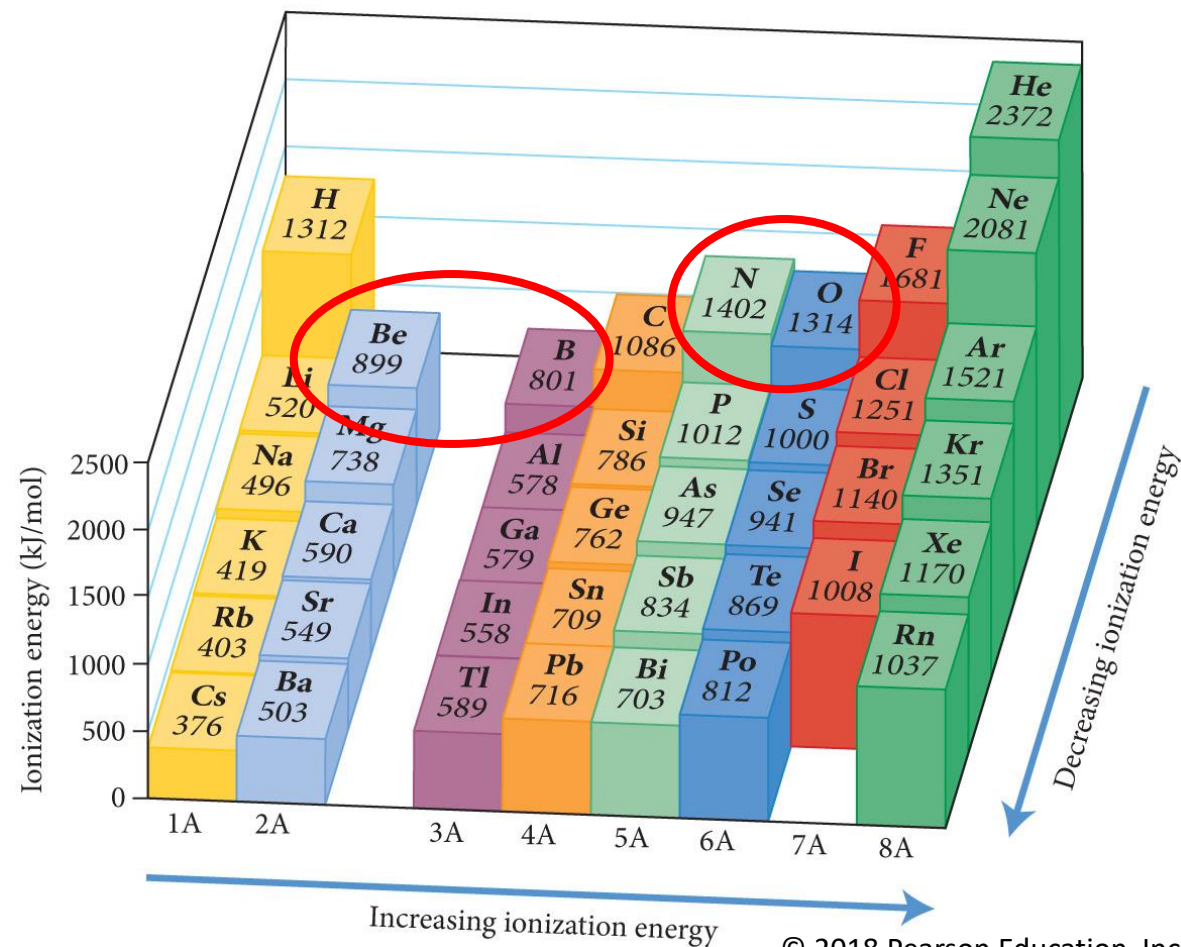


Periodic Trend: First Ionization Energy

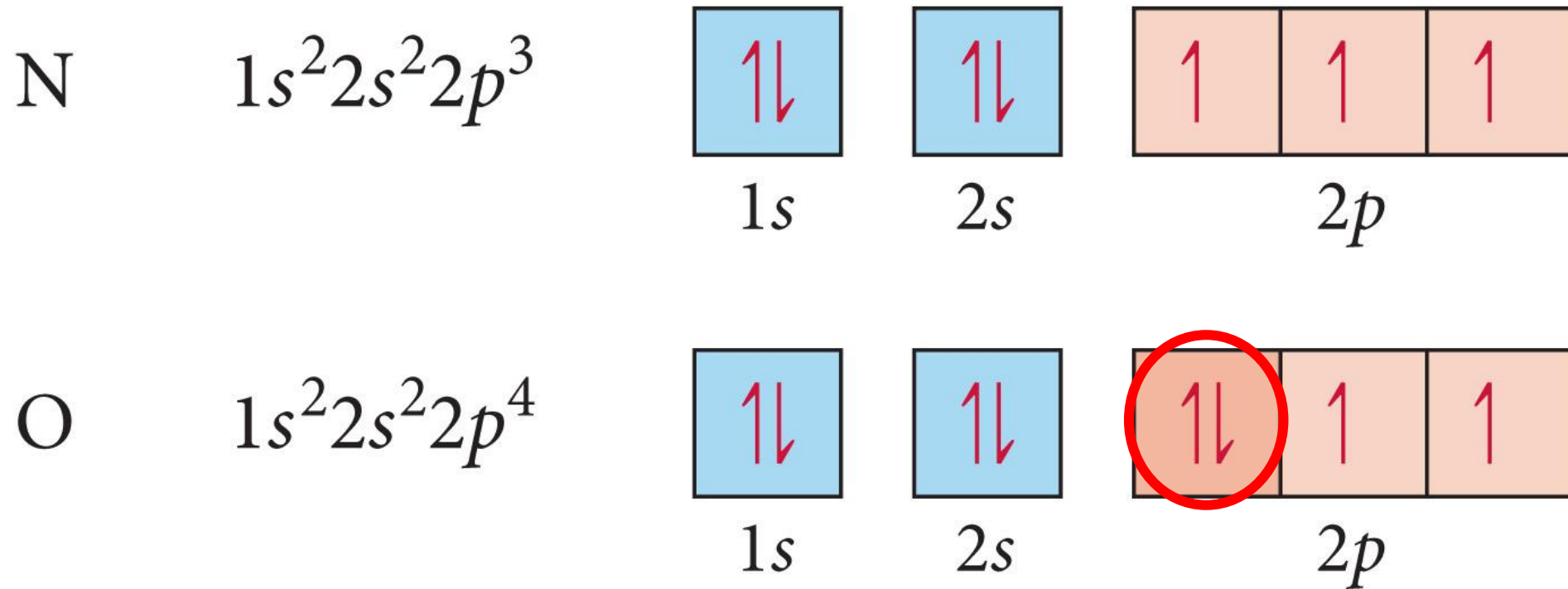


ionization energy = amount of energy required to remove an electron *from an atom in the gas phase*

- 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



Group 5A/6A Anomaly in Ionization Energy

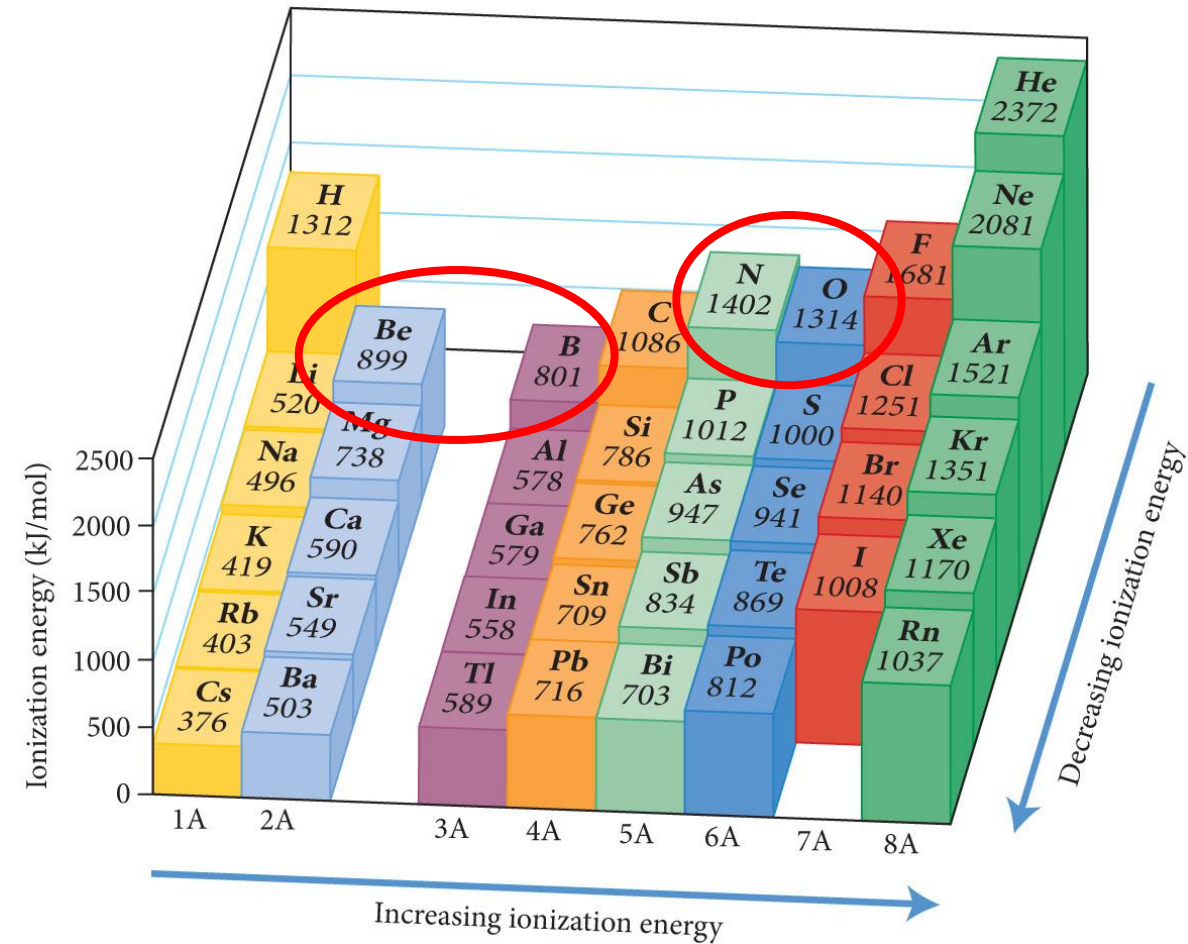


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- removal of an electron from oxygen relieves repulsions caused by two electrons occupying the same orbital
 - explains the anomalies in both ionization energy and electron affinity of Group 5A

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

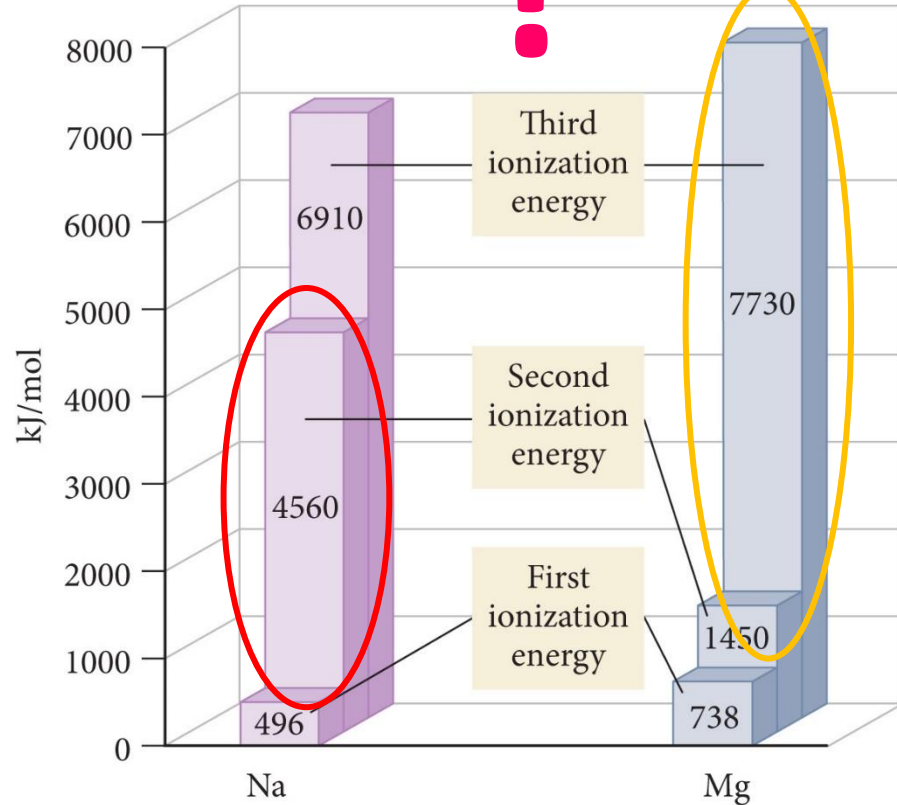


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HINT: MEMEORIZE He is the hardest atom to ionize and derive trend

Successive Ionization Energies

?



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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

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- 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:

$$IE_1 = 1,086 \text{ kJ/mol}$$

$$IE_2 = 2,353 \text{ kJ/mol}$$

$$IE_3 = 4,621 \text{ kJ/mol}$$

$$IE_4 = 6,223 \text{ kJ/mol}$$

$$IE_5 = 37,831 \text{ kJ/mol}$$

$$IE_6 = 47,277 \text{ kJ/mol}$$

Periodic Trend: Electron Affinity



electron affinity = amount of energy associated when an **atom in the gas phase** 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**
- successive electron affinities typically are endothermic/require energy due to increased repulsion of adding electrons to something already bearing a negative charge

Electron Affinities (kJ/mol)

1A							8A
H -73	2A	3A	4A	5A	6A	7A	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

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Metals Metalloids Nonmetals

Periods

1A 1 2A 2 3A 13 4A 14 5A 15 6A 16 7A 17

1 H 2 He 3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne

2 11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar

3 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

4 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

5 55 Cs 56 Ba 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

6 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 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 Md 102 No 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 Lv 116 Ts 117 Og

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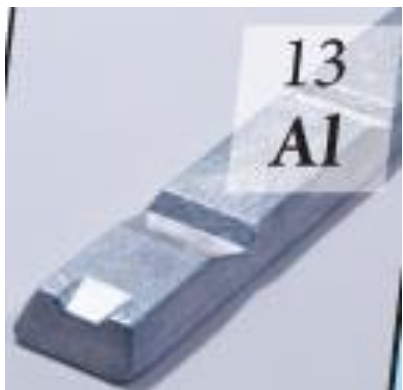
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- metals vs. nonmetals vs. metalloids on periodic table

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Metals vs. Nonmetals: Properties



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