PERIODICITY

PERIODICITY

- the trends in the behavior of the elements.

-arises from the periodic patterns in the electron configuration of the element.

Periodic Laws: “When the elements are arranged in order of increasing atomic masses, certain sets of properties recur periodically.”

(Dmitri Mendeleev and Lothar Meyer, 1869)

“The properties of the elements are periodic functions of their atomic numbers.”

(Henrey Mooseley, 1913)

*The rearrangement of the periodic table was based on the X-ray spectra of elements obtained by Mooseley.

Table 8.1 Mendeleev's Predicted Properties of Germanium ("eka Silicon" and Its Actual Properties

Property	Predicted Properties of eka Silicon(E)	Actual Properties of Germanium (Ge)
atomic mass	72amu	72.61amu
appearance	gray metal	gray metal
density	5.5g/cm^3	5.32g/cm^3
molar volume	13cm^3/mol	13.65cm^3/mol
specific heat capacity	0.31J/g*K	0.32J/g*K
oxide formula	EO_2	GeO_2
oxide density	4.7g/cm^3	4.23g/cm^3
sulfide formula and solubility	ES_2; insoluble in H_2O; soluble in aqueous $(NH_4)_2S$	GeS_2; insoluble in H_2O; soluble in aqueous $(NH_4)_2S$
chloride formula (boiling point)	ECl_4; (<100^{0}C)	$GeCl_4$; (84^{0}C)
chloride density	1.9g/cm^3	1.844g/cm^3
element preparation	reduction of K_2EF_6 with sodium	reduction of K_2GeF_6 with sodium

The Periodic Table

- an arrangement of the atoms in increasing order of their atomic numbers that collects atoms with similar properties in vertical columns.

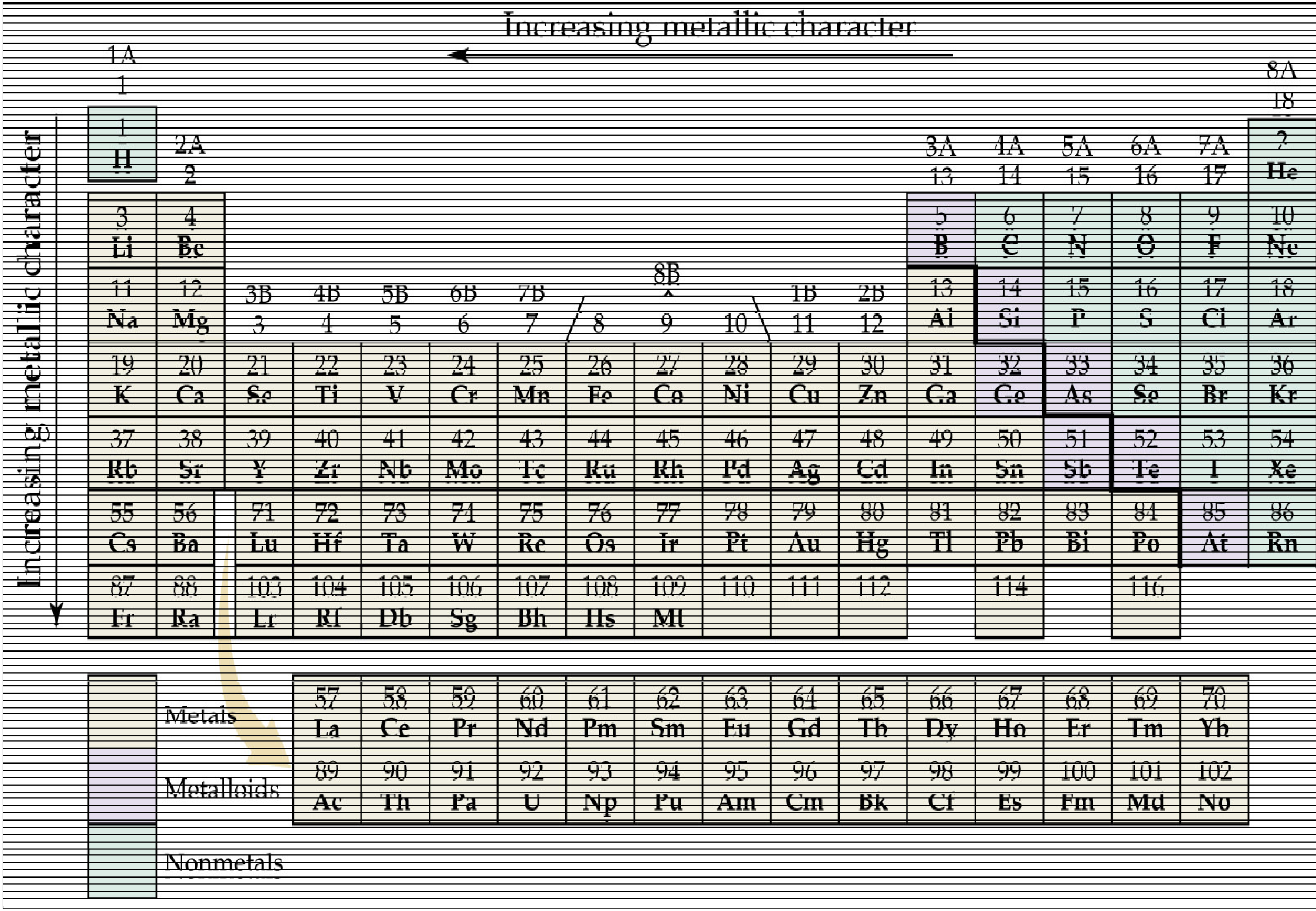
FAMILY OR GROUP – elements in a column

PERIOD/SERIES – elements in a row.

A. Based on Properties

1. **Metals** - have lustrous, silvery, appearance
- good conductors of heat and electricity, malleable and ductile
- high melting point, lose electrons
- elements in the left side and in the center of the periodic table.

2. **Nonmetals**
- nonconductors, nonmalleable, nonductile and have no metallic luster
- elements on the right side of the periodic table.



Increasing metallic character
Increasing metallic character
1A 1
2A 2
3A 13
4A 14
5A 15
6A 16
7A 17
8A 18
3B 3
4B 4
5B 5
6B 6
7B 7
8B
8
9
10
1B 11
2B 12
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
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
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
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
87 Fr
88 Ra
103 Lr
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110
111
112
114
116
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
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
Metals
Metalloids
Nonmetals

B. Based on Their Electronic Configuration

1. Representative/Main Group Elements – elements in which the last electron added enters an s or p orbital in the outermost shell but in which this shell in incomplete.

- found in Groups 1A-7A

2. Transition Elements – elements that have filled or partially-filled inner d subshell

- found in Groups 1B – 8B

3. Inner Transition Elements – elements that have filled or partially-filled inner f subshell; lanthanoids and actinoids

4. Noble/Inert Gases – have filled valence subshell; elements in Group 8A; very stable since closed shell (ns2np6)

PROPERTIES OF SOME GROUPS OF ELEMENTS

1. Group 1A, Alkali Metals

- with typical valence of 1 corresponding to their s1 electronic structure.
- light metals, soft and lustrous but so reactive that they have to be kept from air or moisture (most reactive metals)
- their hydroxides have an intensive basic or alkaline action, hence members of this family are referred to as alkali metals.

2. Group 2A, Alkaline Earth Metals

- also active metals but generally less than the alkali metals
- has 2 valence electrons
- all form chlorides that are water-soluble and carbonates that are water-insoluble

3. Hydrogen

- a colorless, diatomic gas and the first element in the periodic table
- does not belong to any family
- has a 1s1 electronic configuration

4. Group 6A, Chalcogens

- chalk former; the increase in metallic character down the group is clearly evident.

5. Group 7A, Halogens

- listed in the order of increasing atomic weight, melting and boiling points

- fluorine and chlorine are gases (pale yellow and greenish yellow respectively); bromine is a volatile liquid (reddish brown); iodine is a volatile solid (deep violet)

- order of increasing activity:Iodine<bromine<chlorine<fluorine
- their H compounds are all acids
- all combine readily with metals to from salts

6. Group 8A, Noble Gases

- all colorless and exhibit little or no reactivity
- they seldom form stable compounds with other elements

Review

- Valence electrons
- Valence shell
- Nonvalence electrons (S)
- Atomic Number (Z)

Factors Affecting Atomic Orbital Energies

The Effect of Nuclear Charge ($Z_{effective}$)

Higher nuclear charge lowers orbital energy (stabilizes the system) by increasing nucleus-electron attractions.

THE GREATER INTERACTION BETWEEN NUCLEUS AND ELECTRONS, HIGHER z_{eff}

The Effect of Electron Repulsions (Shielding)

Electron shielding decreases the effective nuclear charge

Figure 8.3 **The effect of nuclear charge on orbital energy.**

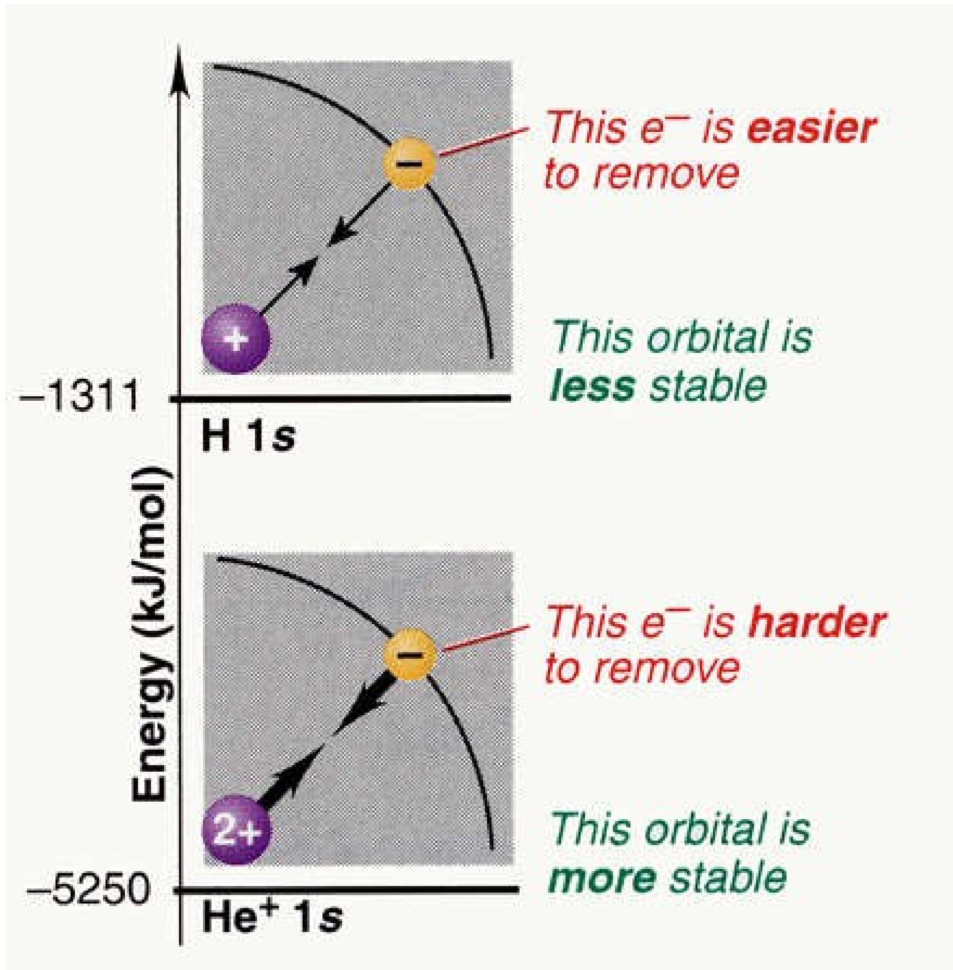
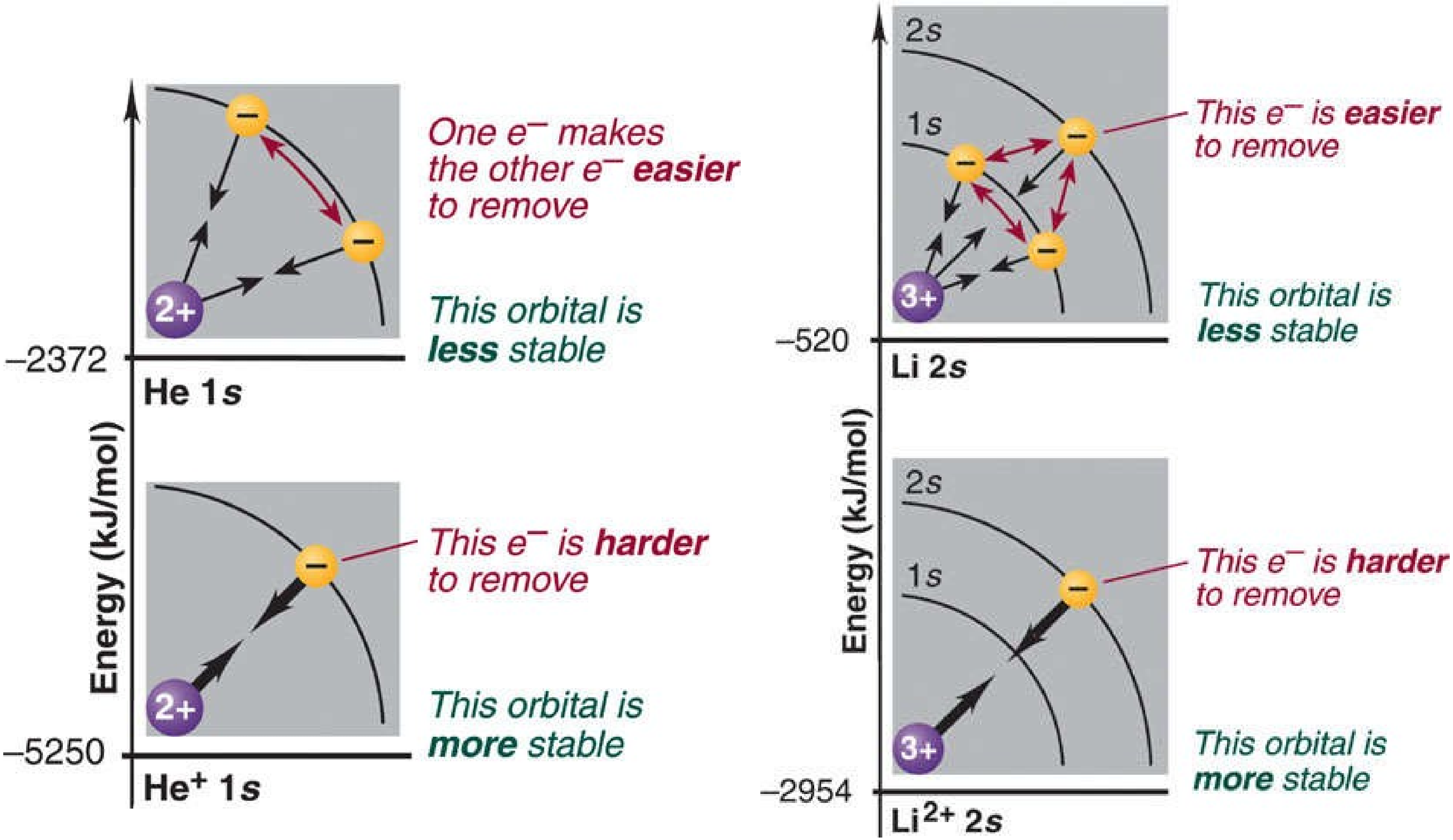


Figure 8.4 **Shielding**



PERIODIC TRENDS

- ATOMIC SIZE/ATOMIC RADIUS – derived from the distance between atoms when bonded together.

TRENDS:

- within each period (row) – atomic radius decrease from left to right (increasing atomic number and number of electrons, thus increasing effective nuclear charge, Zeff)

  Ex.. C, N, F

- within each group (column) – atomic radius increases from top to bottom (increasing n or number of shells)

Figure 8.14

Defining metallic and covalent radii

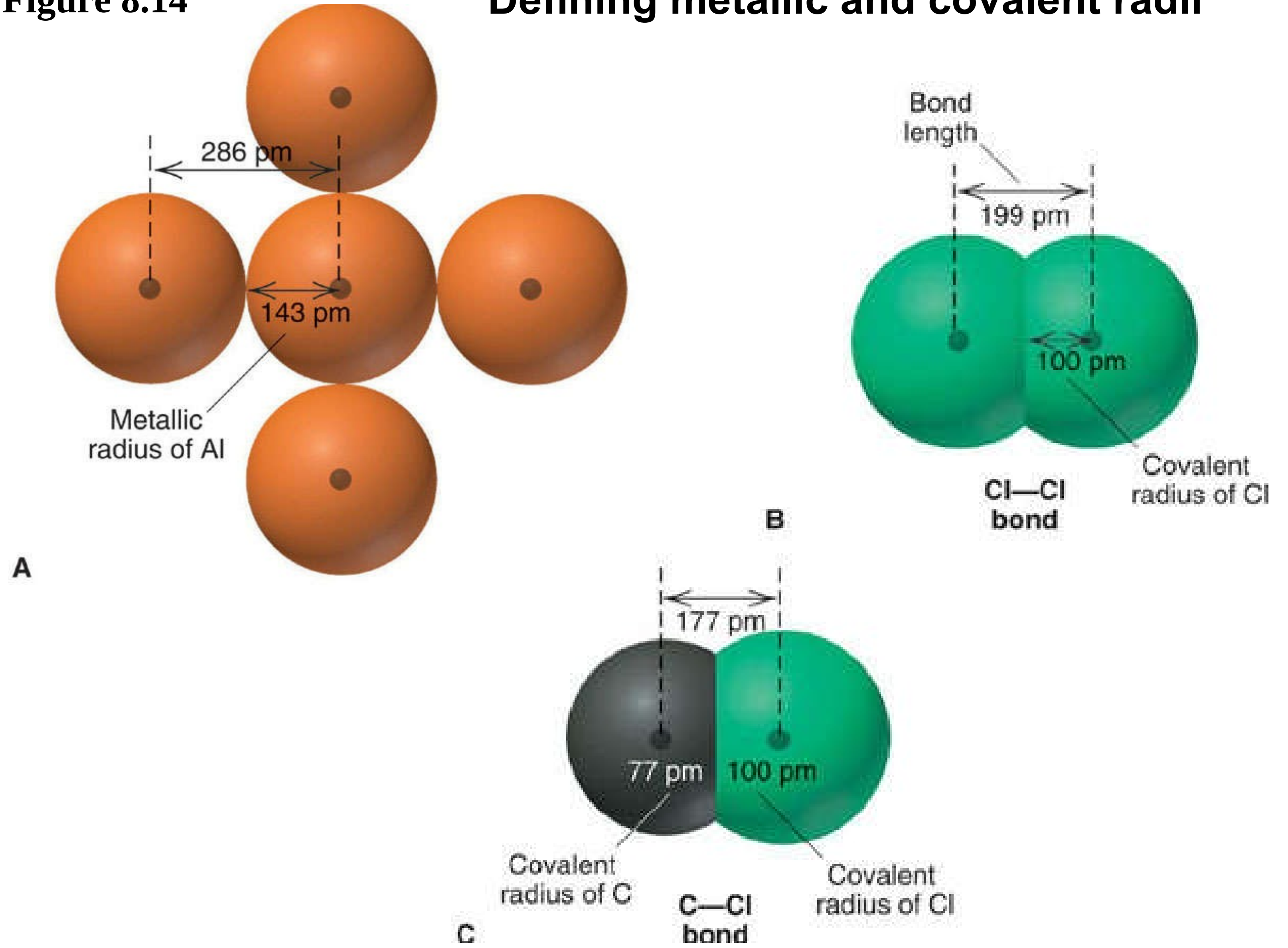
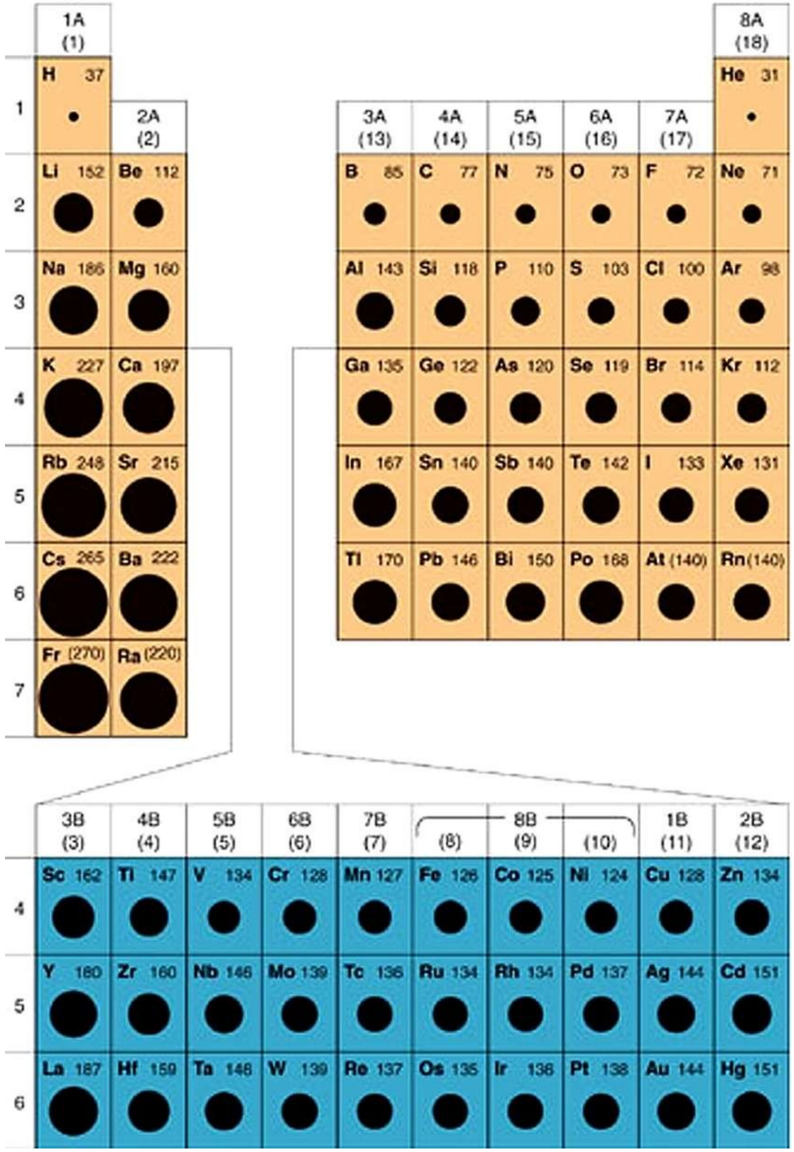


Figure 8.15

Atomic radii of the main-group and transition elements.



SAMPLE PROBLEM 8.3 Ranking Elements by Atomic Size

PROBLEM: Using only the periodic table (not Figure 8.15)m rank each set of main group elements in order of *decreasing* atomic size:

(a) Ca, Mg, Sr **(b)** K, Ga, Ca **(c)** Br, Rb, Kr **(d)** Sr, Ca, Rb

PLAN: Elements in the same group increase in size and you go down; elements decrease in size as you go across a period.

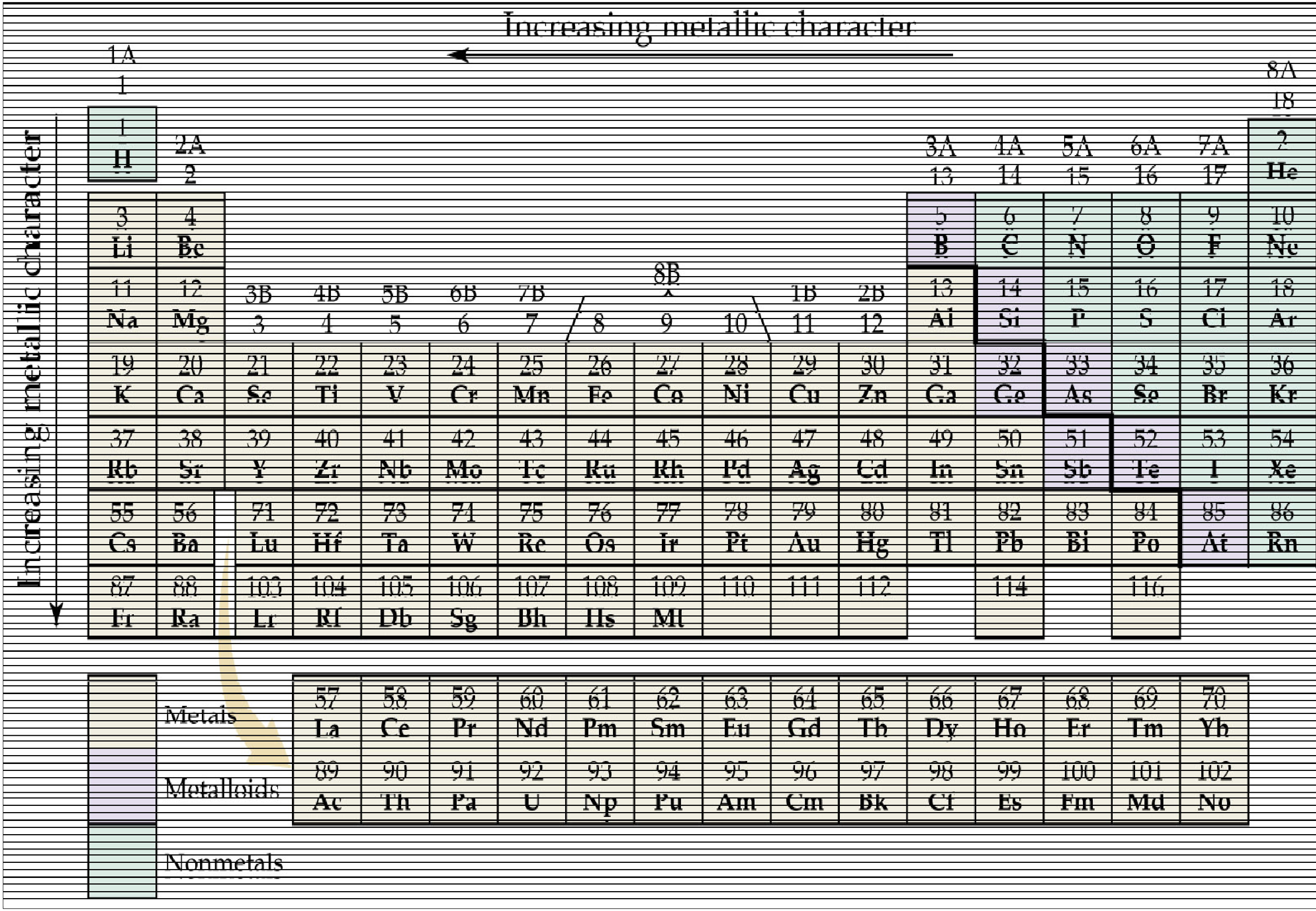
SOLUTION:

(a) Sr > Ca > Mg These elements are in Group 2A(2).

(b) K > Ca > Ga These elements are in Period 4.

(c) Rb > Br > Kr Rb has a higher energy level and is far to the left. Br is to the left of Kr.

(d) Rb > Sr > Ca Ca is one energy level smaller than Rb and Sr. Rb is to the left of Sr.

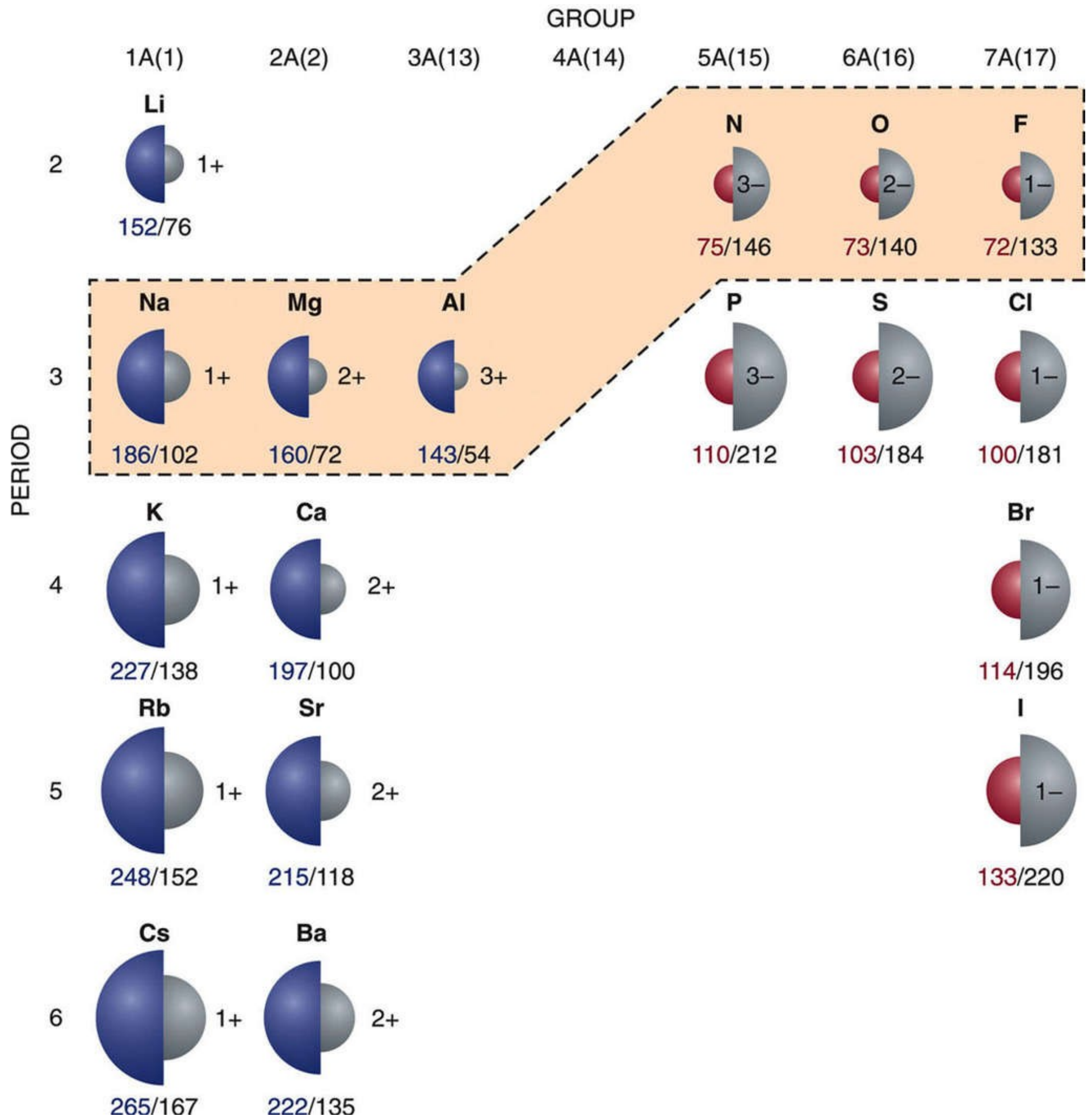

Increasing metallic character
Increasing metallic character
1A 1
2A 2
3A 13
4A 14
5A 15
6A 16
7A 17
8A 18
3B 3
4B 4
5B 5
6B 6
7B 7
8B 8 9 10
1B 11
2B 12
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
19 K
20 Ca
21 Sc
22 Ti
23 V
24 Cr
25 Mn
26 Fe
27 Co
28 Ni
29 Cu
30 Zn
31 Ga
32 Ge
33 As
34 Se
35 Br
36 Kr
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
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
87 Fr
88 Ra
103 Lr
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110
111
112
114
116
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
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
Metals
Metalloids
Nonmetals

2. IONIC SIZE

Cations are generally smaller than the metals from which they were formed.

Anions are generally larger than the nonmetal from which they were formed.

Figure 8.29 **Ionic vs. atomic radius.**



SAMPLE PROBLEM 8.8 Ranking Ions by Size

PROBLEM: Rank each set of ions in order of *decreasing* size, and explain your ranking:

(a) Ca^{2+}, Sr^{2+}, Mg^{2+} **(b)** K^{+}, S^{2-}, Cl^{-} **(c)** Au^{+}, Au^{3+}

PLAN: Compare positions in the periodic table, formation of positive and negative ions and changes in size due to gain or loss of electrons.

SOLUTION:

(a) $Sr^{2+} > Ca^{2+} > Mg^{2+}$

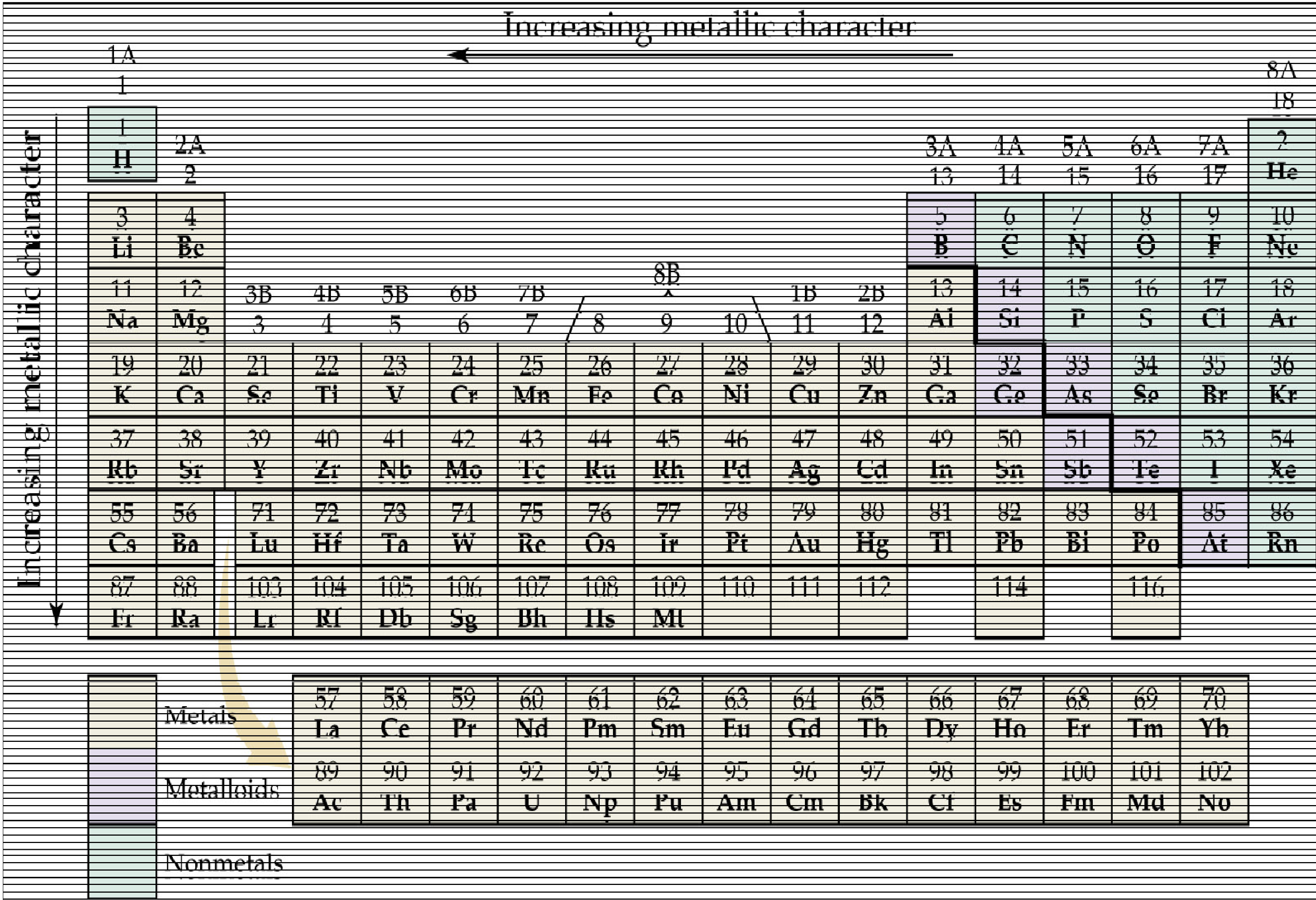
These are members of the same Group (2A/2) and therefore decrease in size going up the group.

(b) $S^{2-} > Cl^{-} > K^{+}$

The ions are isoelectronic; S^{2-} has the smallest Z_{eff} and therefore is the largest while K^{+} is a cation with a large Z_{eff} and is the smallest.

(c) $Au^{+} > Au^{3+}$

The higher the + charge, the smaller the ion.


Increasing metallic character
Increasing metallic character
1A 1
2A 2
3A 13
4A 14
5A 15
6A 16
7A 17
8A 18
3B 3
4B 4
5B 5
6B 6
7B 7
8B 8 9 10
1B 11
2B 12
1 H
2 He
3 Li
4 Be
5 B
6 C
7 N
8 O
9 F
10 Ne
11 Na
12 Mg
13 Al
14 Si
15 P
16 S
17 Cl
18 Ar
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
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
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
87 Fr
88 Ra
103 Lr
104 Rf
105 Db
106 Sg
107 Bh
108 Hs
109 Mt
110
111
112
114
116
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
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
Metals
Metalloids
Nonmetals

3. IONIZATION ENERGY – minimum energy required to remove an electron from the ground state of the isolated atom.

FIRST IONIZATION ENERGY (I1) - energy needed to remove the first (outermost) electron); I1 < I2 < I3
*Small atoms are expected to have high IE because their valence electrons are nearer and more strongly attracted to the nucleus.

TRENDS: - within each group, IE ↓ with increasing atomic number due to the ↑ in size (↑ n)
- within each period, IE ↑ with increasing atomic number due to increase in Zeff

Figure 8.18 **First ionization energies of the main-group elements.**

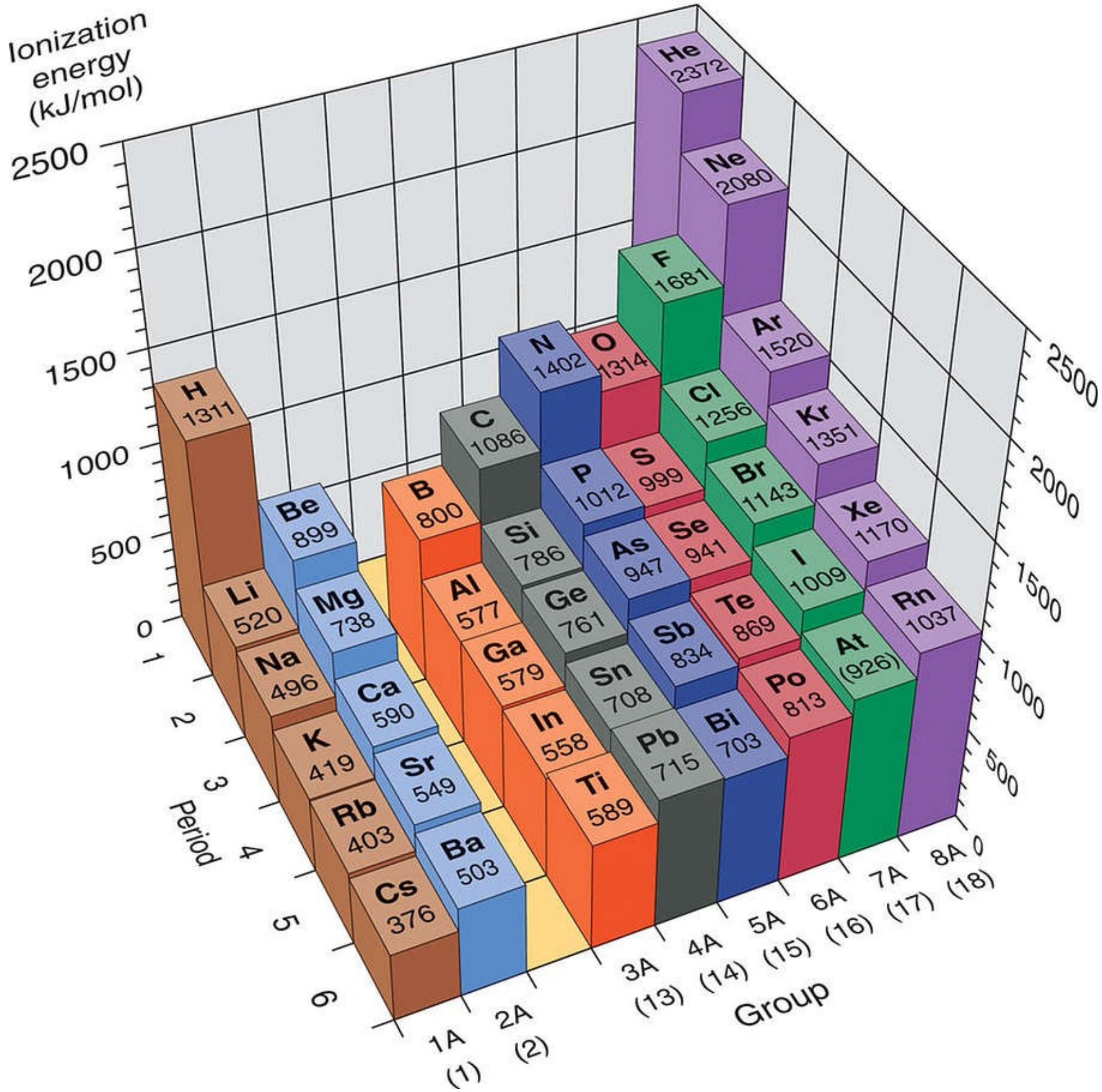
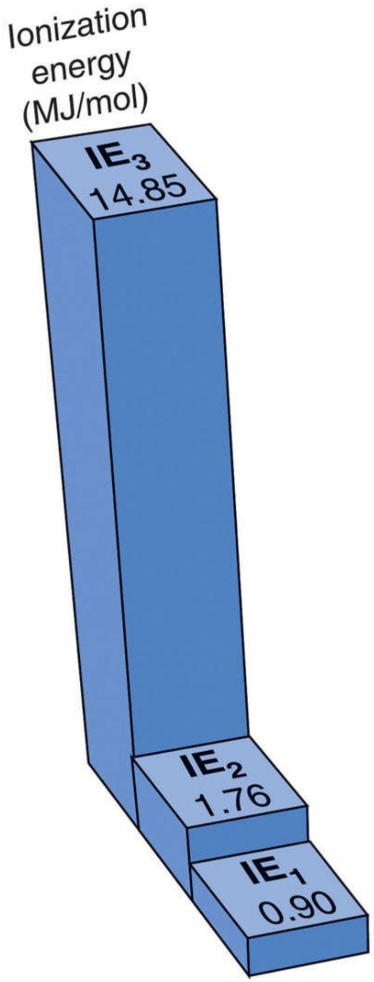


Figure 8.19

The first three ionization energies of beryllium (in MJ/mol).



For more data on sequential ionization energies of the elements, go to http://www.webelements.com or click on the button below.

SAMPLE PROBLEM 8.4 Ranking Elements by First Ionization Energy

PROBLEM: Using the periodic table only, rank the elements in each of the following sets in order of *decreasing* IE_1:

(a) Kr, He, Ar **(b)** Sb, Te, Sn **(c)** K, Ca, Rb **(d)** I, Xe, Cs

PLAN: IE decreases as you proceed down in a group; IE increases as you go across a period.

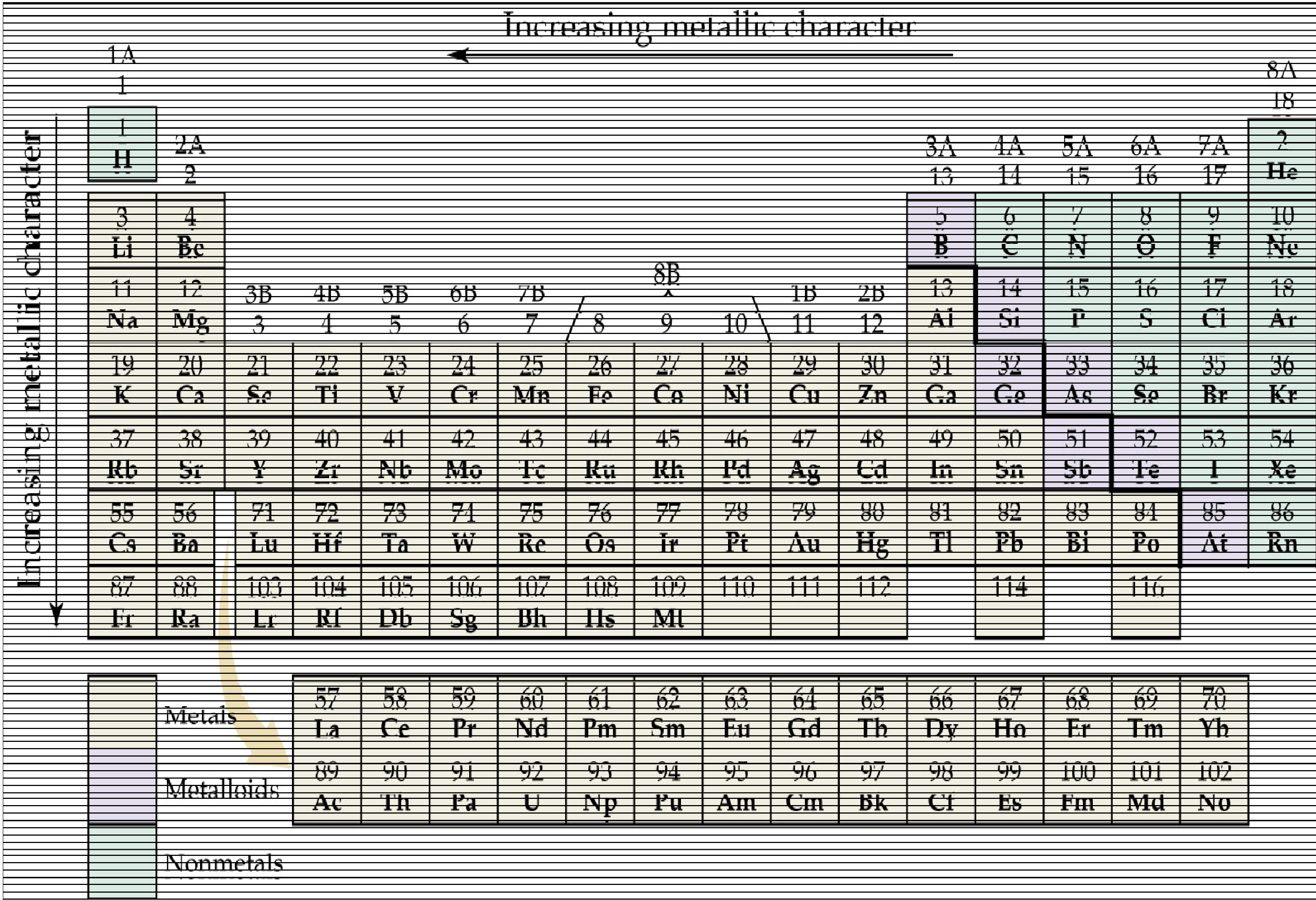
SOLUTION:

(a) He > Ar > Kr — Group 8A(18) - IE decreases down a group.

(b) Te > Sb > Sn — Period 5 elements - IE increases across a period.

(c) Ca > K > Rb — Ca is to the right of K; Rb is below K.

(d) Xe > I > Cs — I is to the left of Xe; Cs is furtther to the left and down one period.



Increasing metallic character
Increasing metallic character
1A 1
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4A 14
5A 15
6A 16
7A 17
8A 18
3B 3
4B 4
5B 5
6B 6
7B 7
8B 8 9 10
1B 11
2B 12
1 H
2 He
3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
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
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
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
87 Fr 88 Ra 103 Lr 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110 111 112 114 116
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
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
Metals
Metalloids
Nonmetals

4. ELECTRON AFFINITY – energy change associated to the addition of an e- to a gaseous atom/ion (an exothermic process)

- The higher the Z_{eff}, the higher the EA

* Large atoms are expected to have low EA because their valence electrons are farther from the nucleus.

*Small atoms have high EA because added electron will be closest to the nucleus.

TRENDS:- increasing across a period (left to right)

- decreasing across a group (top to bottom)

Figure 8.20 **Electron affinities of the main-group elements.**

1A (1)	2A (2)	3A (13)	4A (14)	5A (15)	6A (16)	7A (17)	8A (18)
H −72.8							He (0.0)
Li −59.6	Be (+18)	B −26.7	C −122	N +7	O −141	F −328	Ne (+29)
Na −52.9	Mg (+21)	Al −42.5	Si −134	P −72.0	S −200	Cl −349	Ar (+35)
K −48.4	Ca (+186)	Ga −28.9	Ge −119	As −78.2	Se −195	Br −325	Kr (+39)
Rb −46.9	Sr (+146)	In −28.9	Sn −107	Sb −103	Te −190	I −295	Xe (+41)
Cs −45.5	Ba (+46)	Tl −19.3	Pb −35.1	Bi −91.3	Po −183	At −270	Rn (+41)

5. ELECTRONEGATIVITY – is the ability of a bonded atom to attract electrons to itself

*In general, EN increases across a period and decreases down a group

6. METALLICITY

*In general, the metallic character decreases across a period and increases down a group.

Figure 8.21

Trends in three atomic properties.

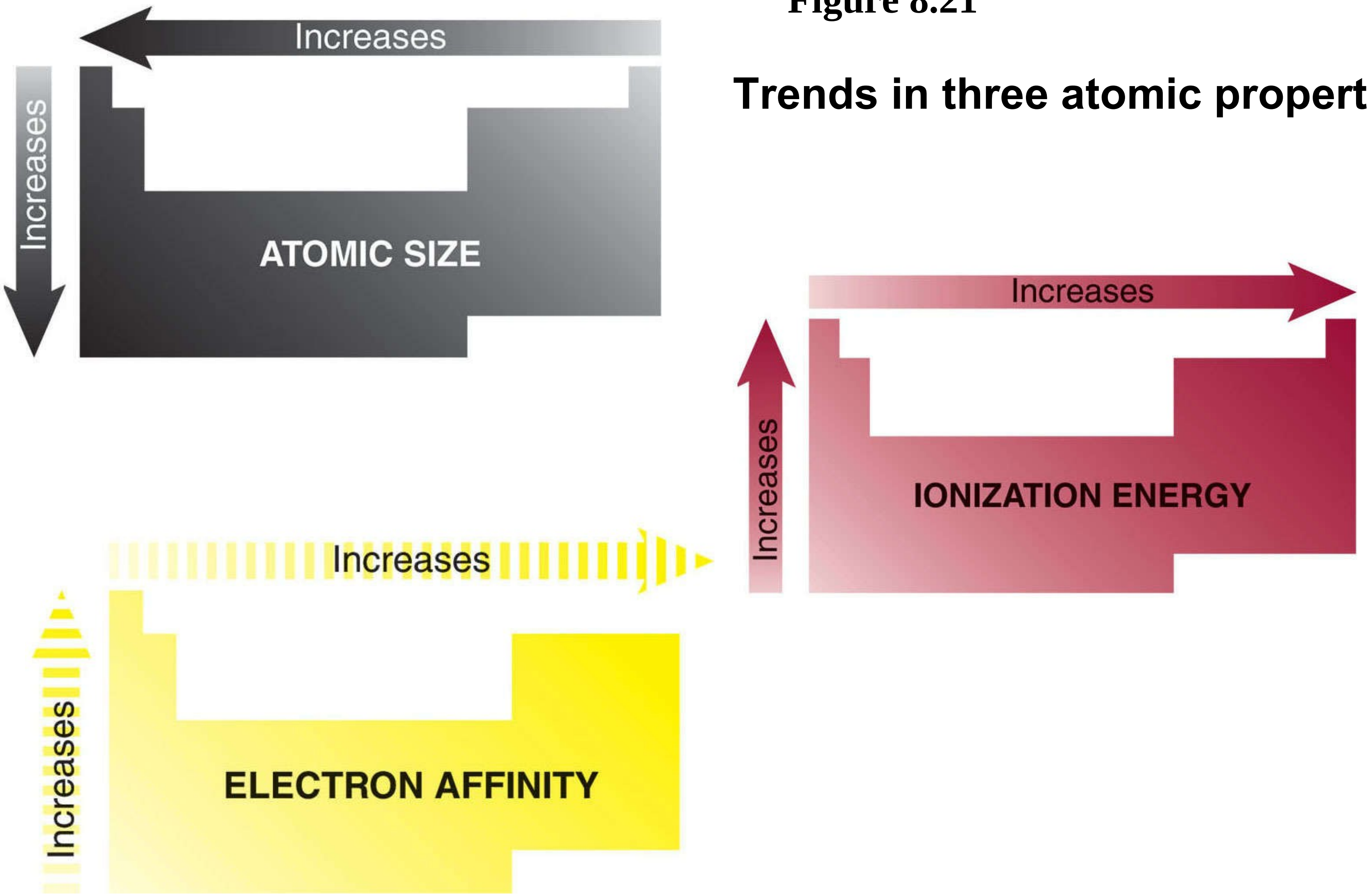
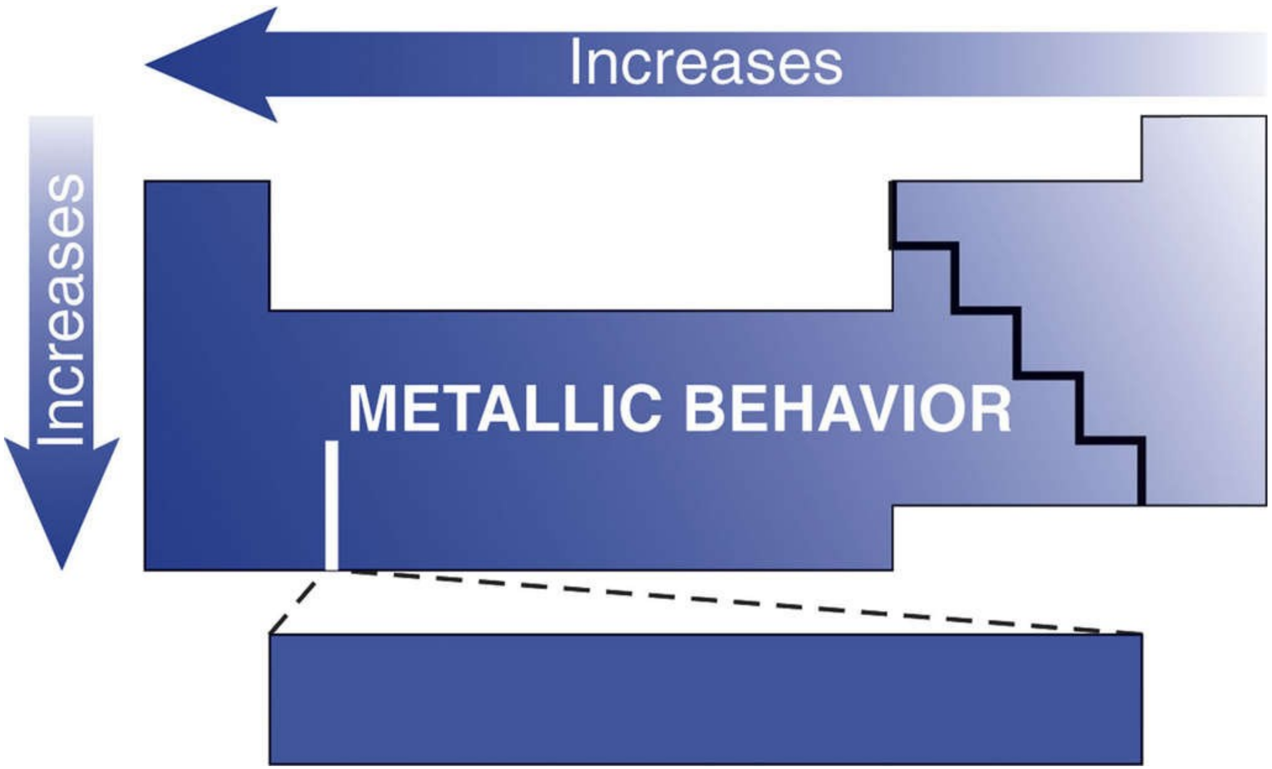


Figure 8.22 **Trends in metallic behavior.**



REACTIVITY

1. Metals – from basic oxides

   metal oxides + water → metal hydroxide

$Na_2O + H_2O \rightarrow 2\ NaOH$ $CaO + H_2O \rightarrow Ca(OH)_2$

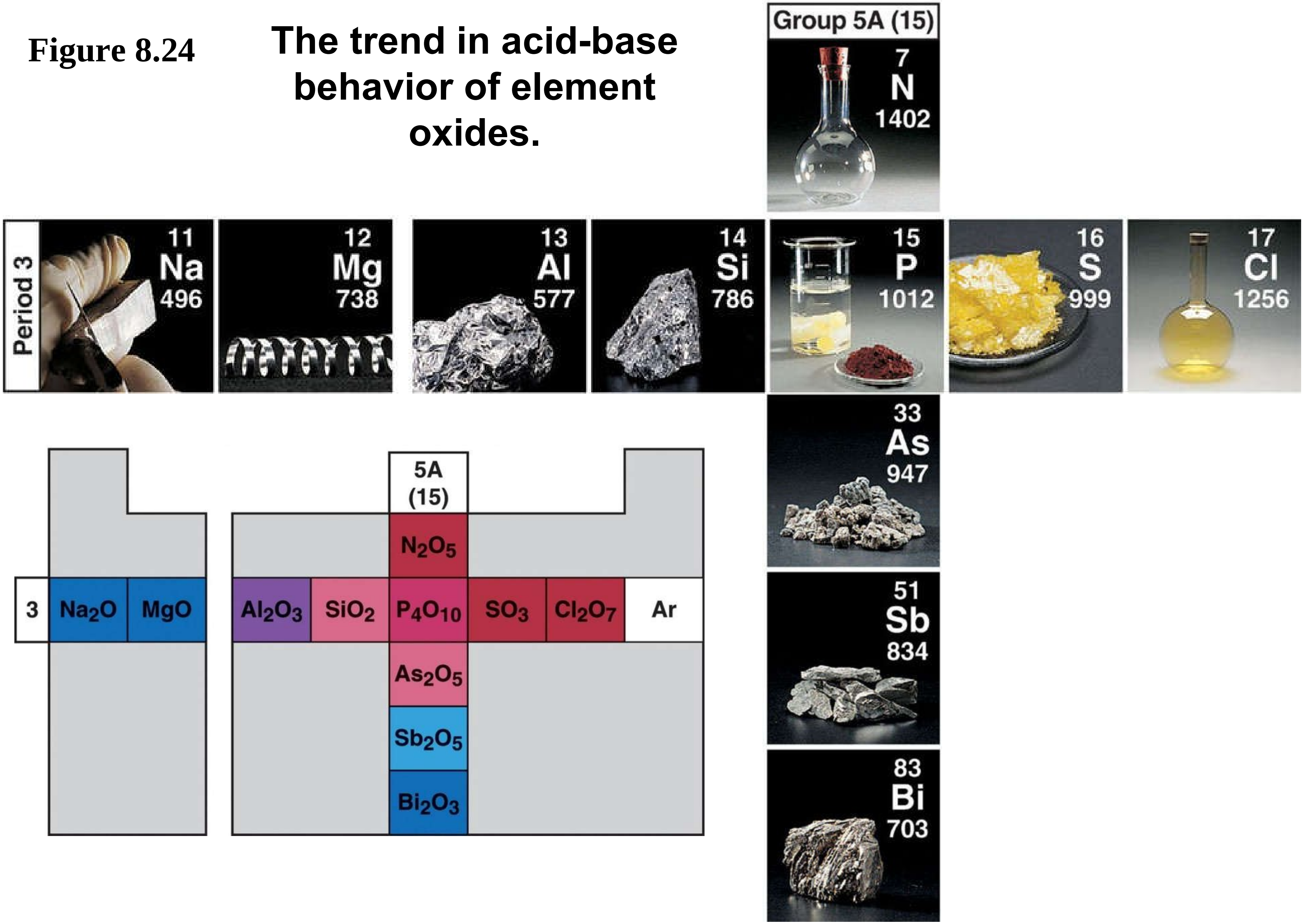
2. Nonmetals – form acidic oxides

   nonmetal oxide + water → acid

CO2 + H2O → H2CO3 P4O10 + 6H2O → 4 H3PO4

Figure 8.24

The trend in acid-base behavior of element oxides.



2nd DEPARTMENTAL EXAM:

February 4, 2012
3-5 PM
LH-C

COVERAGE:

ATOMIC STRUCTURE,ELECTRONIC STRUCTURE,QUANTUM NOS.,ELECTRONIC CONFIGURATION, PERIODICITY