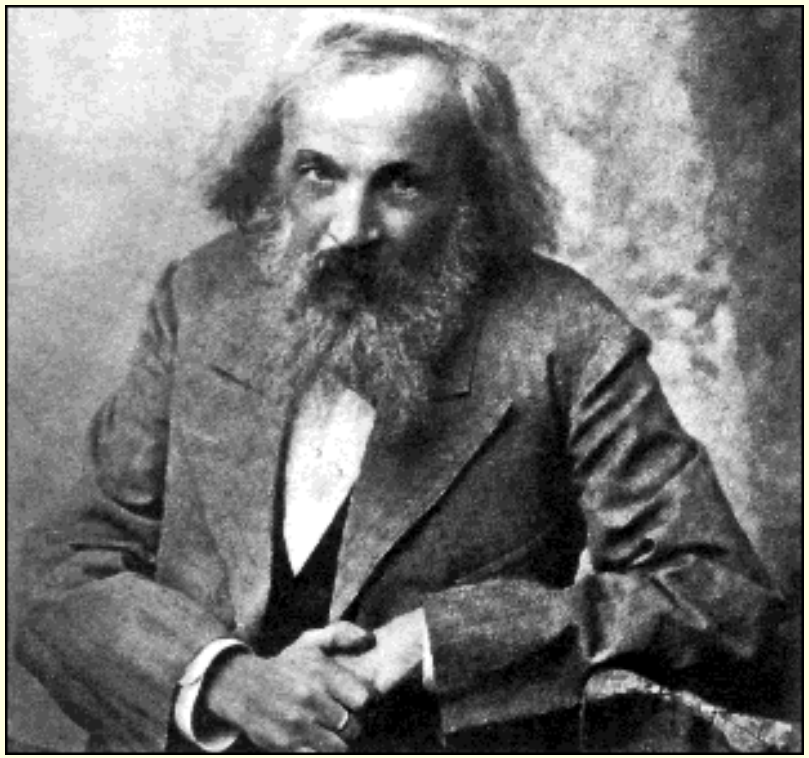
Chapter 5:
The Periodic Law

Section 5.1:
The History of the Periodic Table

- **Dmitri Mendeleev (1869)** – first person to organize the elements in a chart
- Organized about 70 elements by increasing atomic mass
- Left blank spaces for elements which were not discovered yet

Mendeleev's Periodic Table



ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

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

Д. Менделѣевъ

Periodic Table

<u>Henry Moseley (1911)</u> – rearranged Mendeleev's periodic table to the current configuration

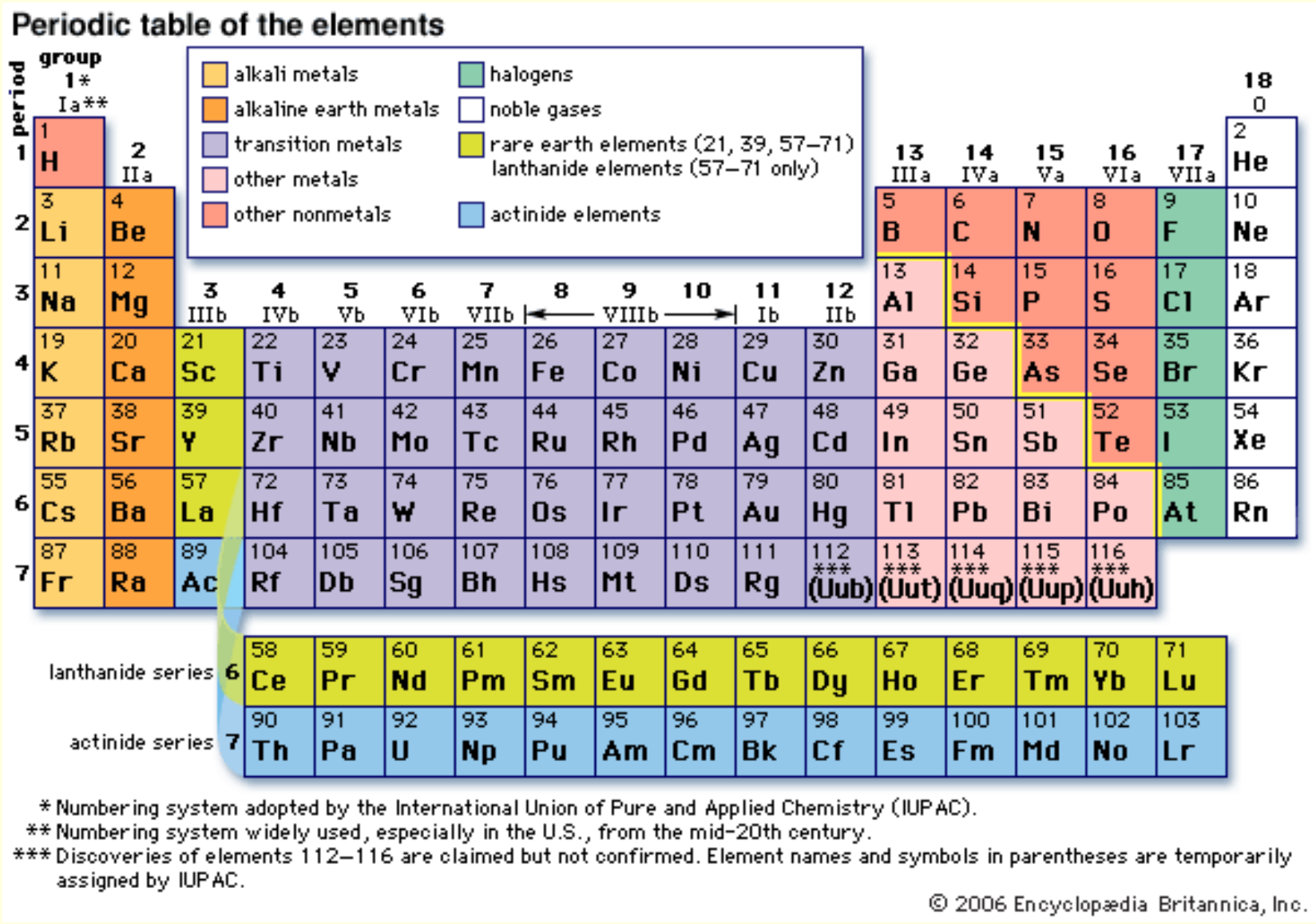
Arranged by increasing atomic number instead!

Also grouped elements by their properties

Periodic Law

When the elements are arranged in order of increasing atomic number, there is a periodic repetition of their physical and chemical properties.

The Modern Periodic Table

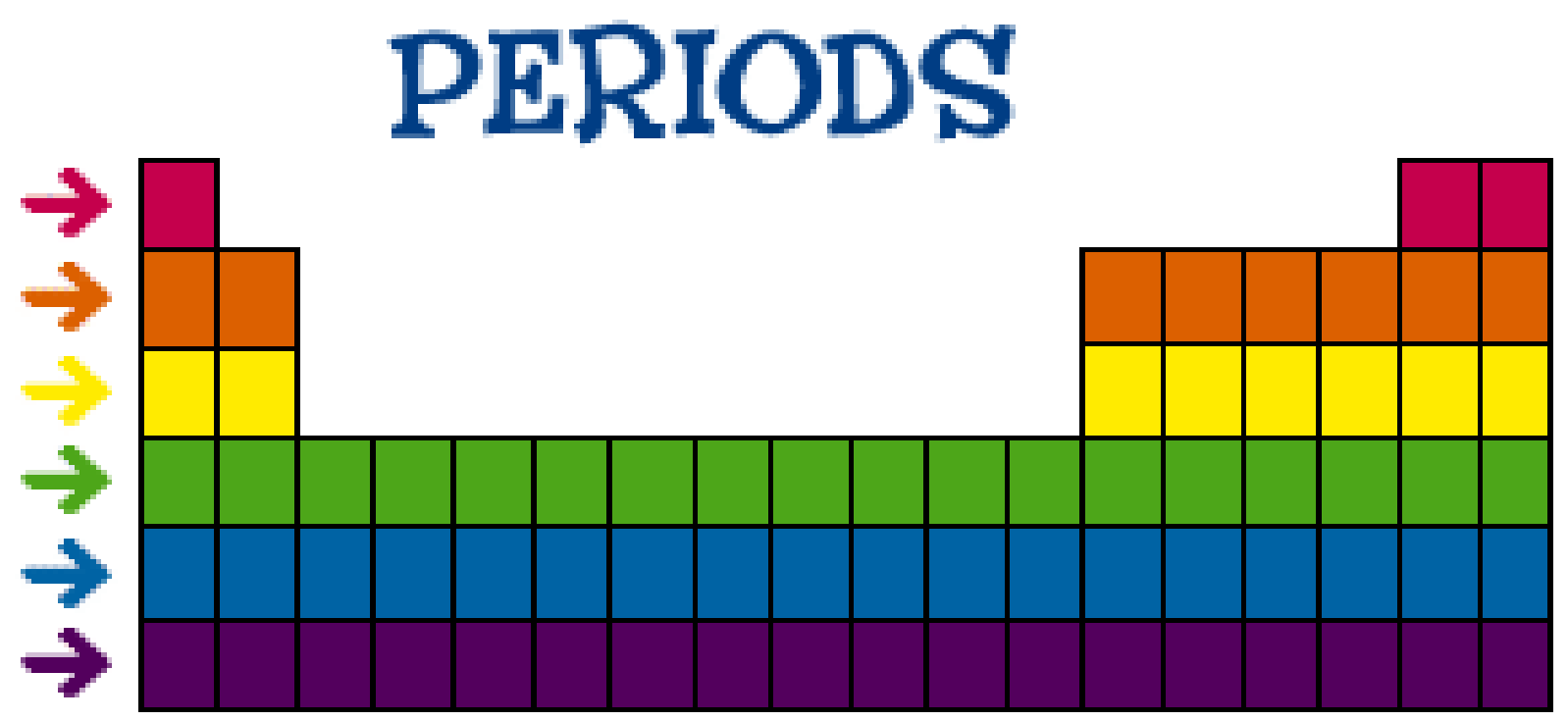


The Modern Periodic Table

Periods:

- The horizontal rows of the table: there are 7 periods
- Properties change as you move across a period
- Properties repeat in a new period

The Modern Periodic Table



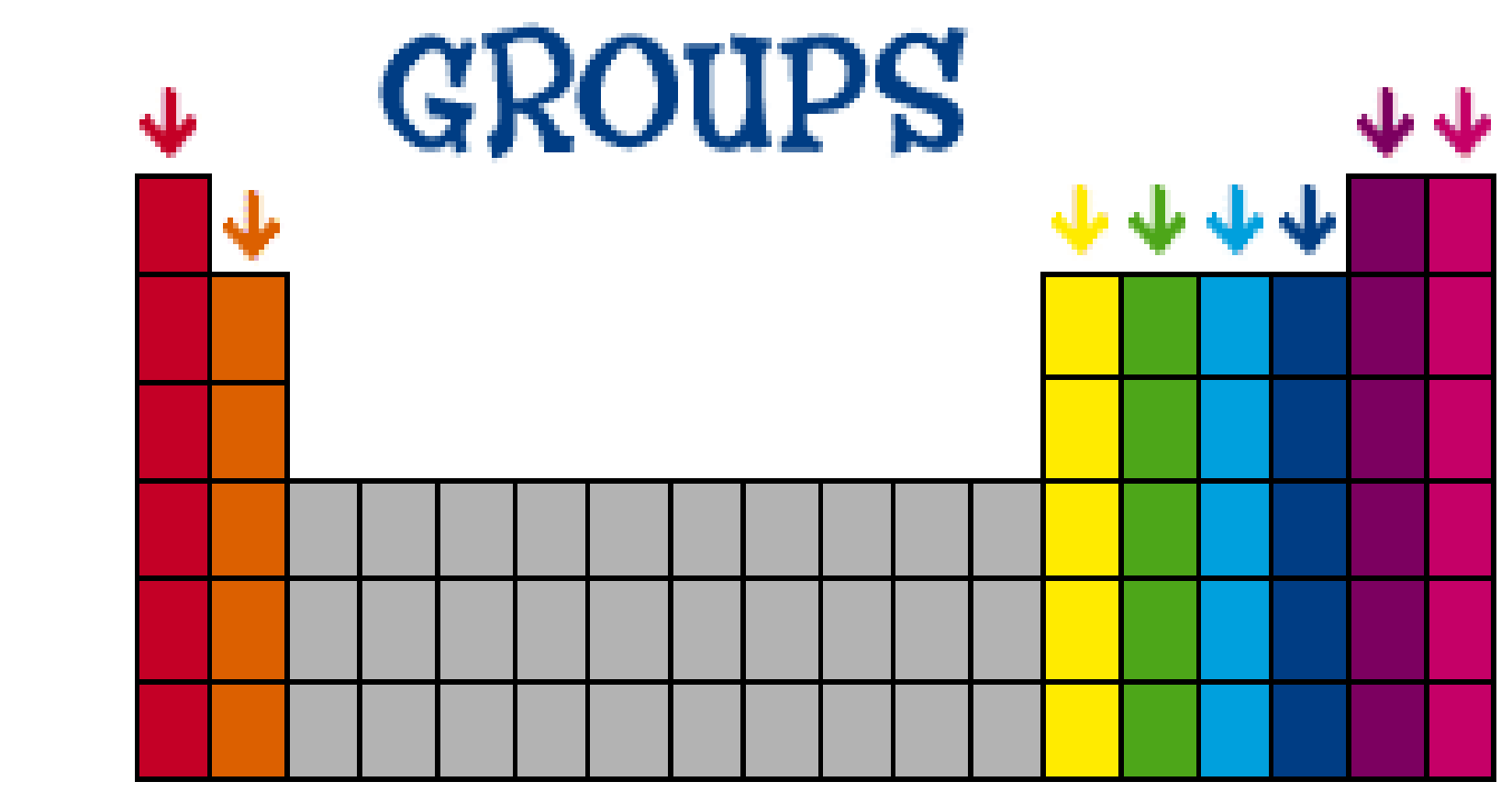
The elements range from atomic number 1 to 113

The Modern Periodic Table

Groups:

- The vertical columns on the table (also called families)
- The elements in a group have similar physical and chemical properties
- Each group has a letter and a number

The Modern Periodic Table



- Group A Main Group elements
- Group B Transition elements

The Modern Periodic Table

Main group elements are divided into three groups:

1. Metals
2. Nonmetals
3. Metalloids

Metals

1. Have high electrical conductivity
2. Have high luster
3. Are ductile: they can be drawn into wires
4. They are malleable: can be formed into shapes

Groups of the Periodic Table

Group 1 = Alkali Metals

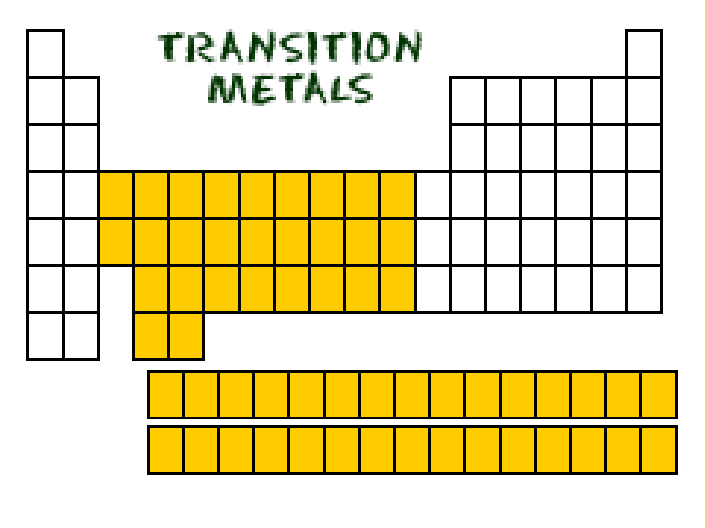
- Violently react with water
- http://video.google.com/videoplay?docid=-2134266654801392897

Group 2 = Alkaline Earth Metals

- Very common in the earth's surface

Groups of the Periodic Table

- Group 3-12 = Transition Metals
  - Most of the common metals
- Lanthanide & Actinide Series = Inner Transition Metals

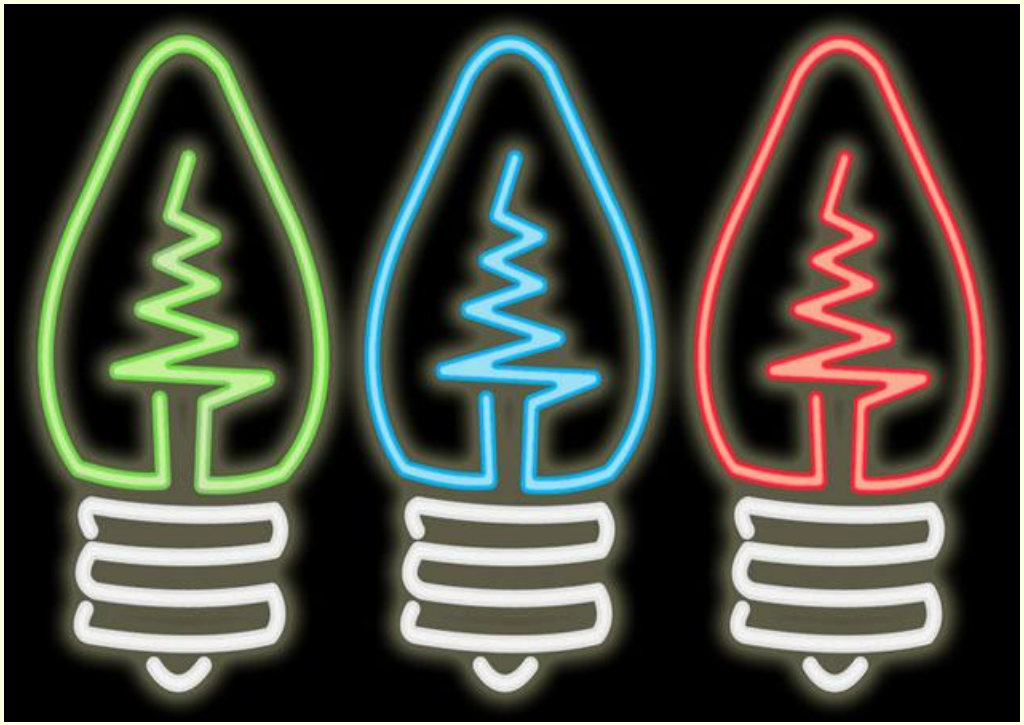


Groups of the Periodic Table

- Group 13-16: Either metals, metalloids, or nonmetal
  - Depends on line of demarcation
- Group 17: Halogens
  - Highly reactive
    - Fluorine
    - Chlorine
    - Bromine
    - Iodine

Groups of the Periodic Table

- Group 18: Noble Gases
  - All gases
  - Do not react or combine with any other element

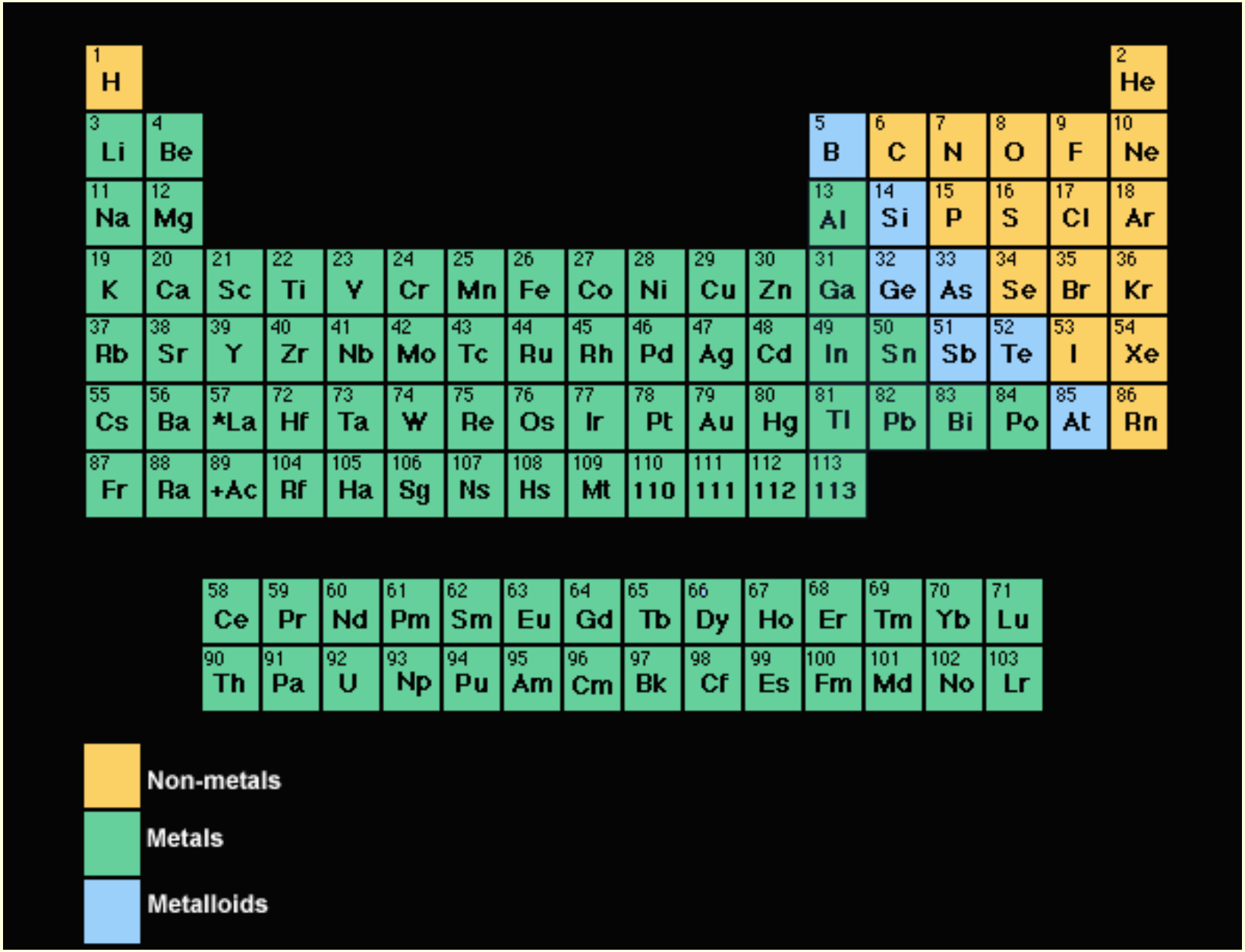


Nonmetals

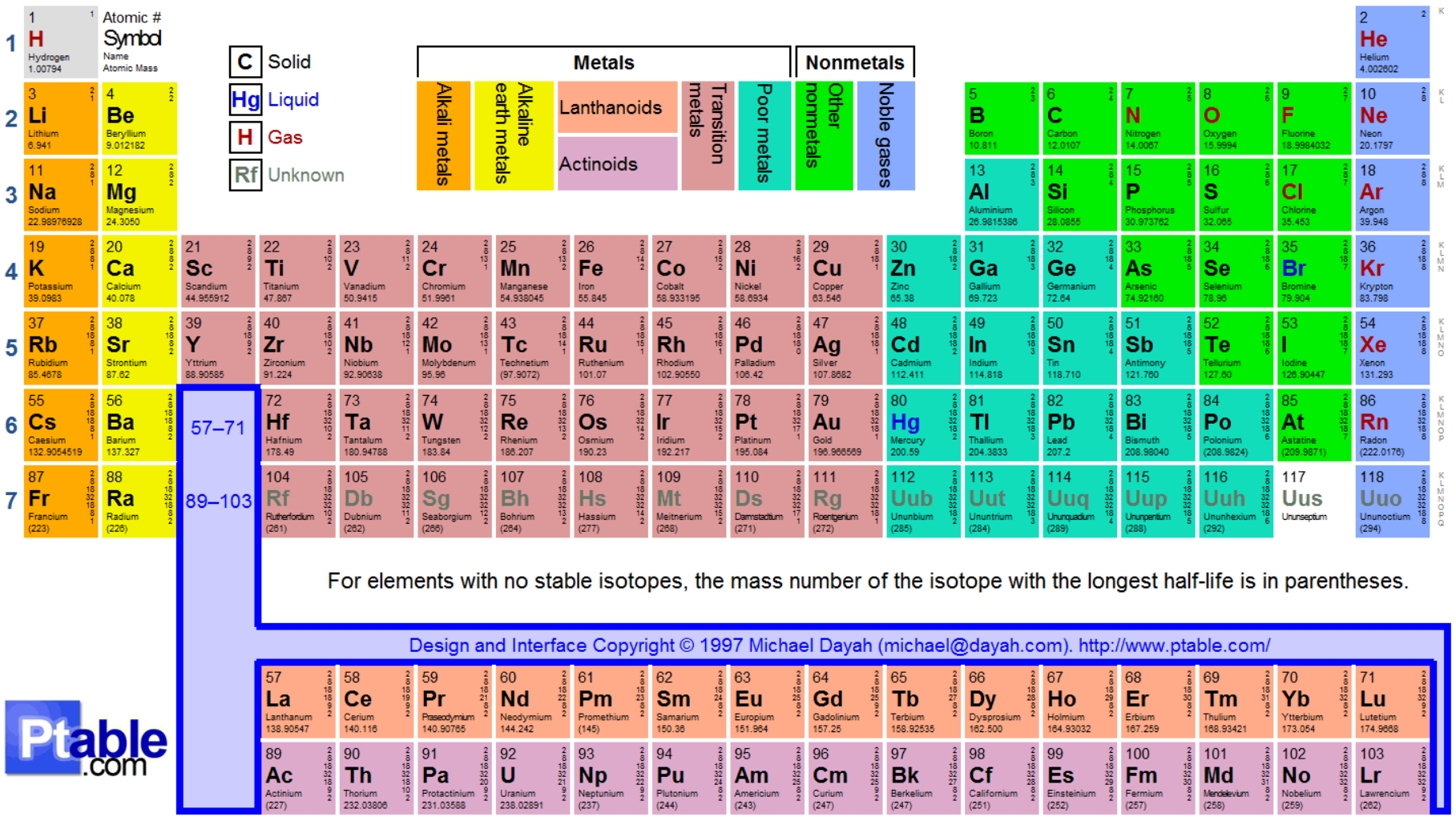
1. Non-lustrous elements
2. Generally poor conductors of electricity
3. Located in the upper right-hand corner of the table

Metalloids

- Elements that border the line between metals and the nonmetals
- Elements with properties are intermediate between those of metals and nonmetals
- Examples: silicon and boron


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
57 *La
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
89 +Ac
104 Rf
105 Ha
106 Sg
107 Ns
108 Hs
109 Mt
110 110
111 111
112 112
113 113
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
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
Non-metals
Metals
Metalloids

Periodic Table of Elements

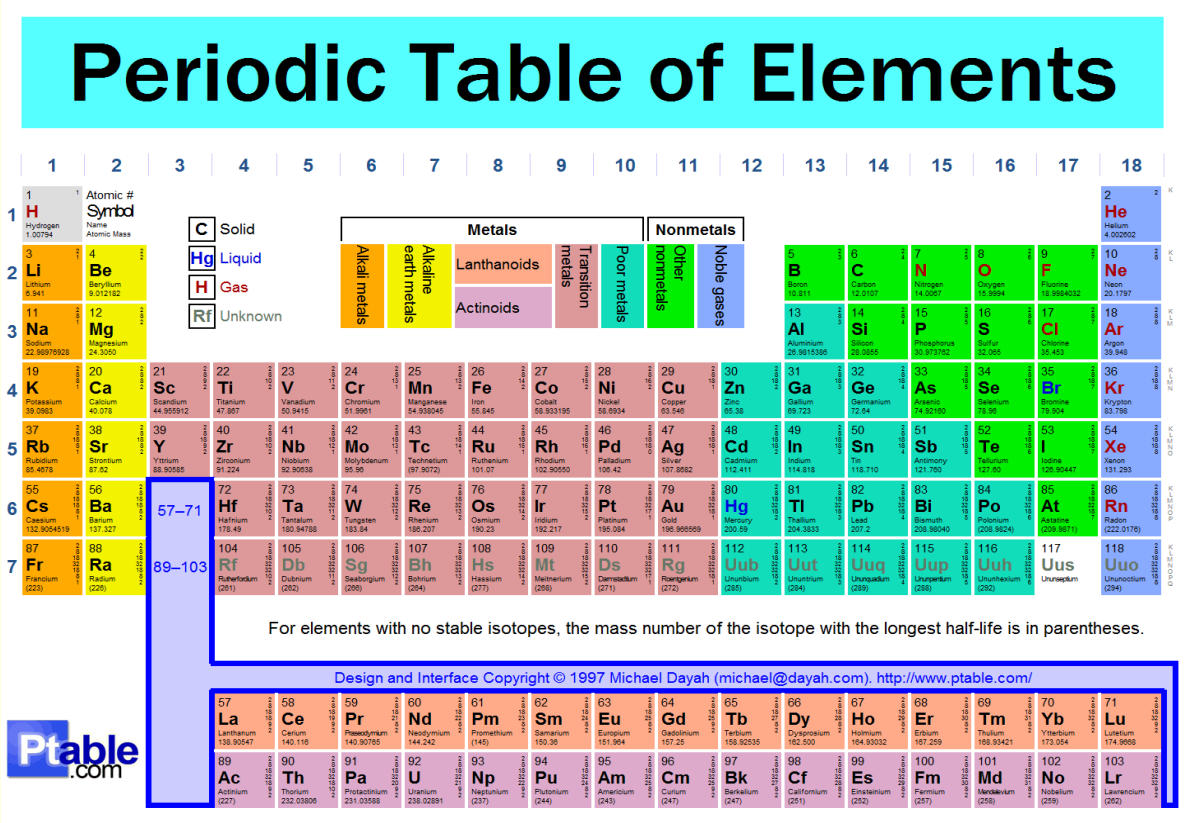


For elements with no stable isotopes, the mass number of the isotope with the longest half-life is in parentheses.

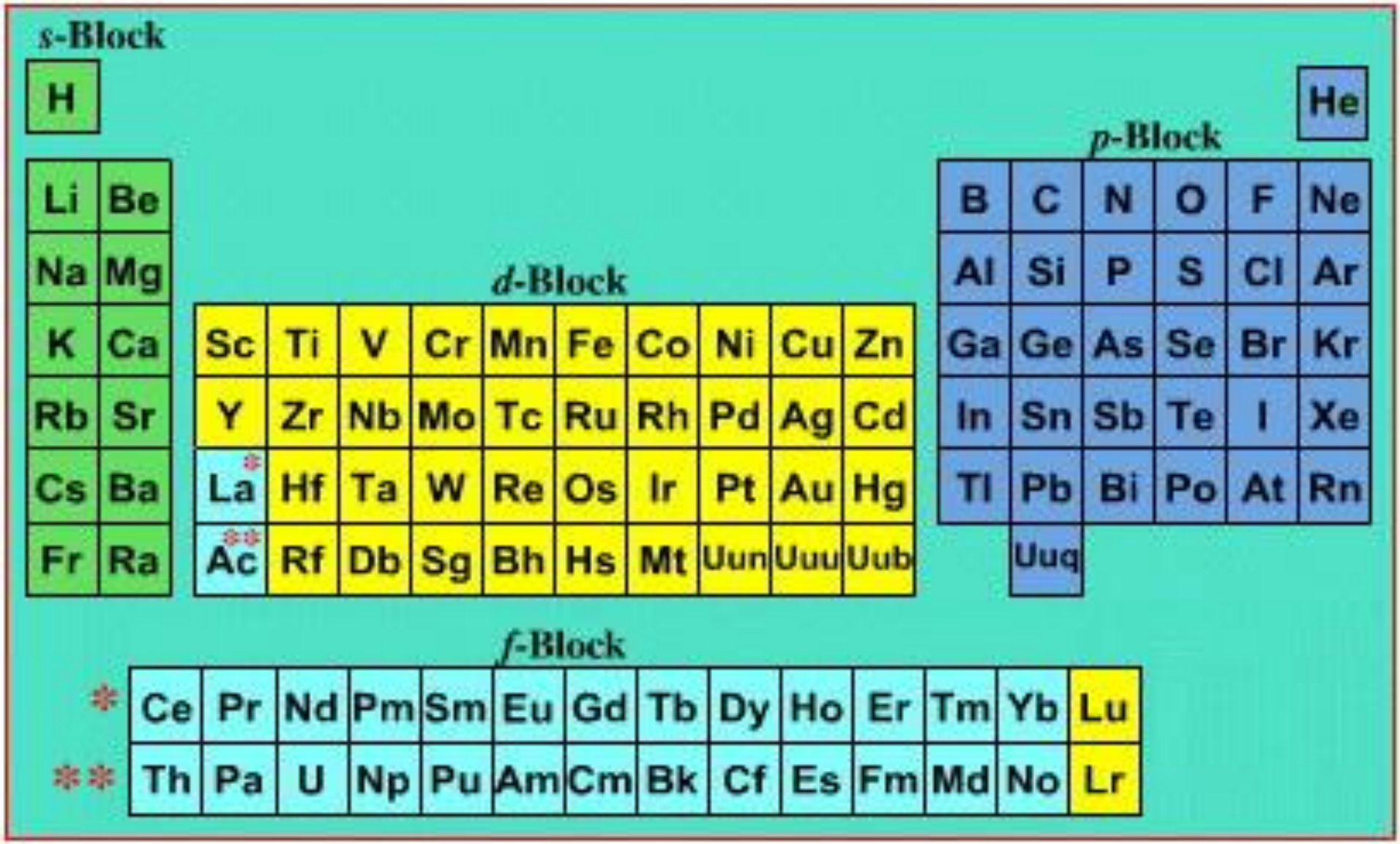
Ptable.com

Section 5.2:
e^- Configurations & the Periodic Table

- **Each group on the periodic table has the same ending electron configuration**



Block Diagram



Section 5.3 – Electron Configurations and Periodic Properties

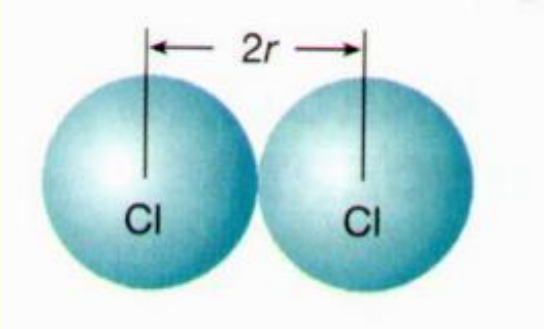
5 Trends to KNOW!

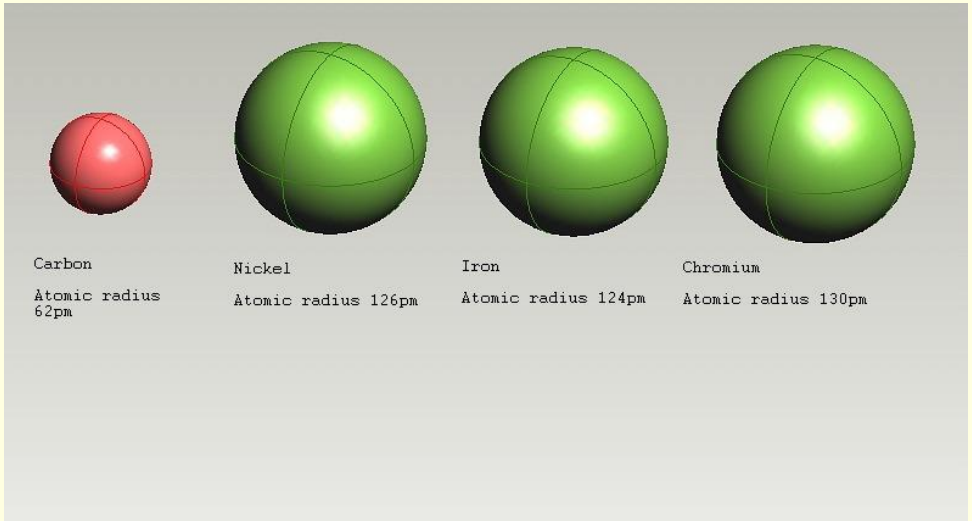
Trends to Know

- 1. Atomic radius
- 2. Ionization energy
- 3. Electron affinity
- 4. Ionic Radius
- 5. Electronegativity

1. Atomic Radius

- **Atomic Radius:** half of the distance between the nuclei of two atoms in a homonuclear diatomic molecule





1. Atomic Radius

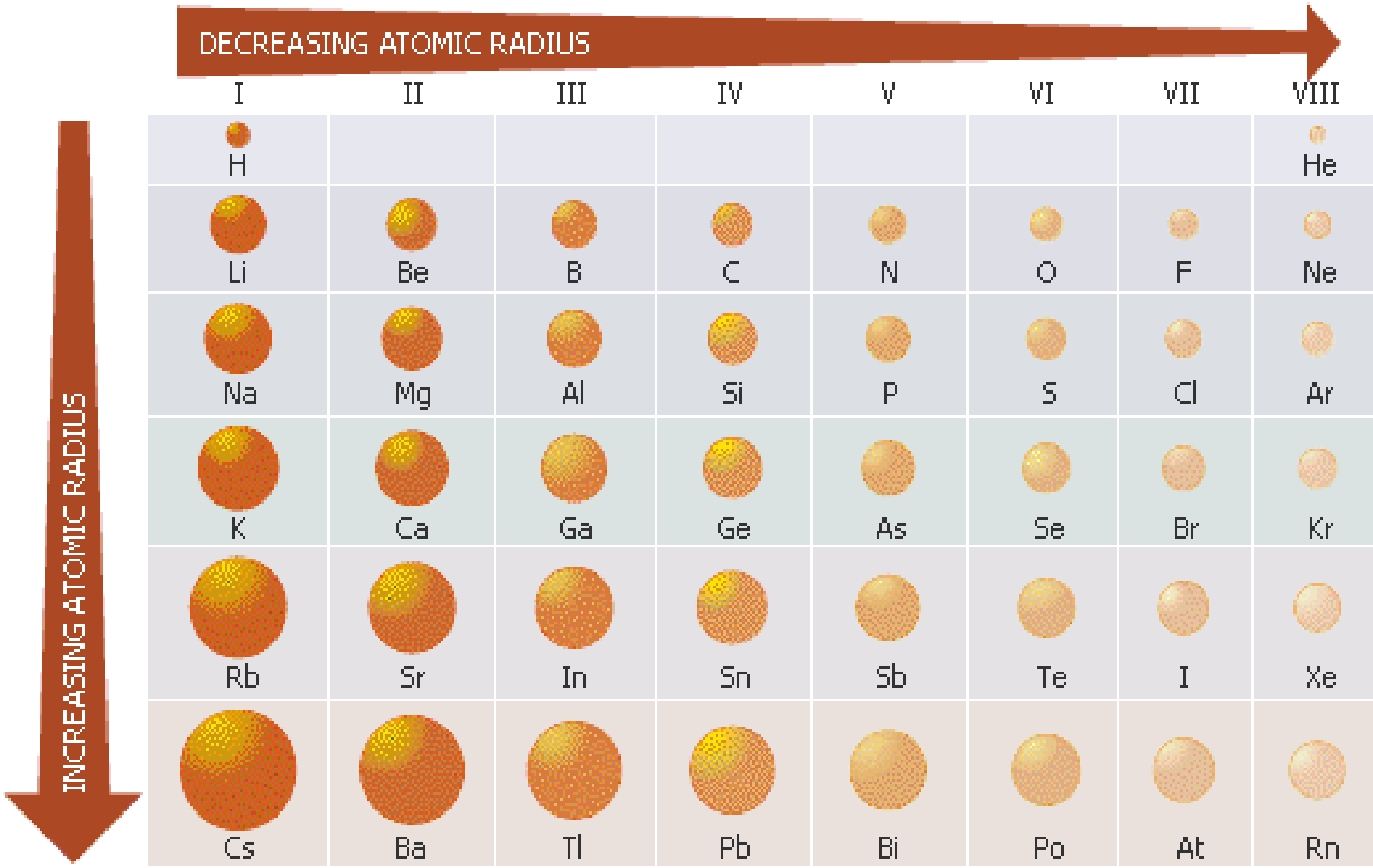
As you travel down a group (↓): atomic radius generally increases

- *Because: e- are added to higher energy levels, further away from the nucleus*

1. Atomic Radius

As you travel across a period (→): Atomic radius generally decreases

- *Because: e- are added to the same energy level and the more positive nucleus pulls on them more strongly*
  - Trend is less pronounced in atoms with more electrons in the occupied energy level (d and f) because of the **shielding effect**
  - *Definition: Inner electrons help protect outer electrons from the effect of the nucleus*

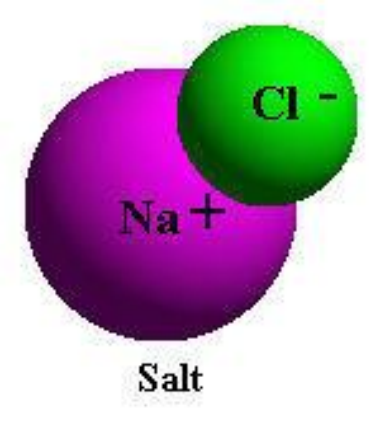

DECREASING ATOMIC RADIUS
INCREASING ATOMIC RADIUS
I
II
III
IV
V
VI
VII
VIII
H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Al
Si
P
S
Cl
Ar
K
Ca
Ga
Ge
As
Se
Br
Kr
Rb
Sr
In
Sn
Sb
Te
I
Xe
Cs
Ba
Tl
Pb
Bi
Po
At
Rn

Your Turn:

Put these elements in order of increasing atomic radius

- C N Li F O
- What is the trend?
- Answer: Li > C > N > O > F

2. Ions



- Ions = charged atoms
  - Have different numbers of electrons
- Cations = positively charged atoms
  - have less electrons then protons
- Anions = negatively charged atoms
  - Have more electrons then protons

2. Ionization Energy

- **Ionization Energy:** the energy needed to remove an electron from a neutral atom, forming a positive ion
  - **first ionization energy:** energy required to remove the first outermost electron
  - **second ionization energy:** energy required to remove an electron from a 1^+ ion, making it a 2^+ ion (Table 3 p 155)

2. Ionization Energy

As you travel down a group (↓): the first ionization energy ***decrease***

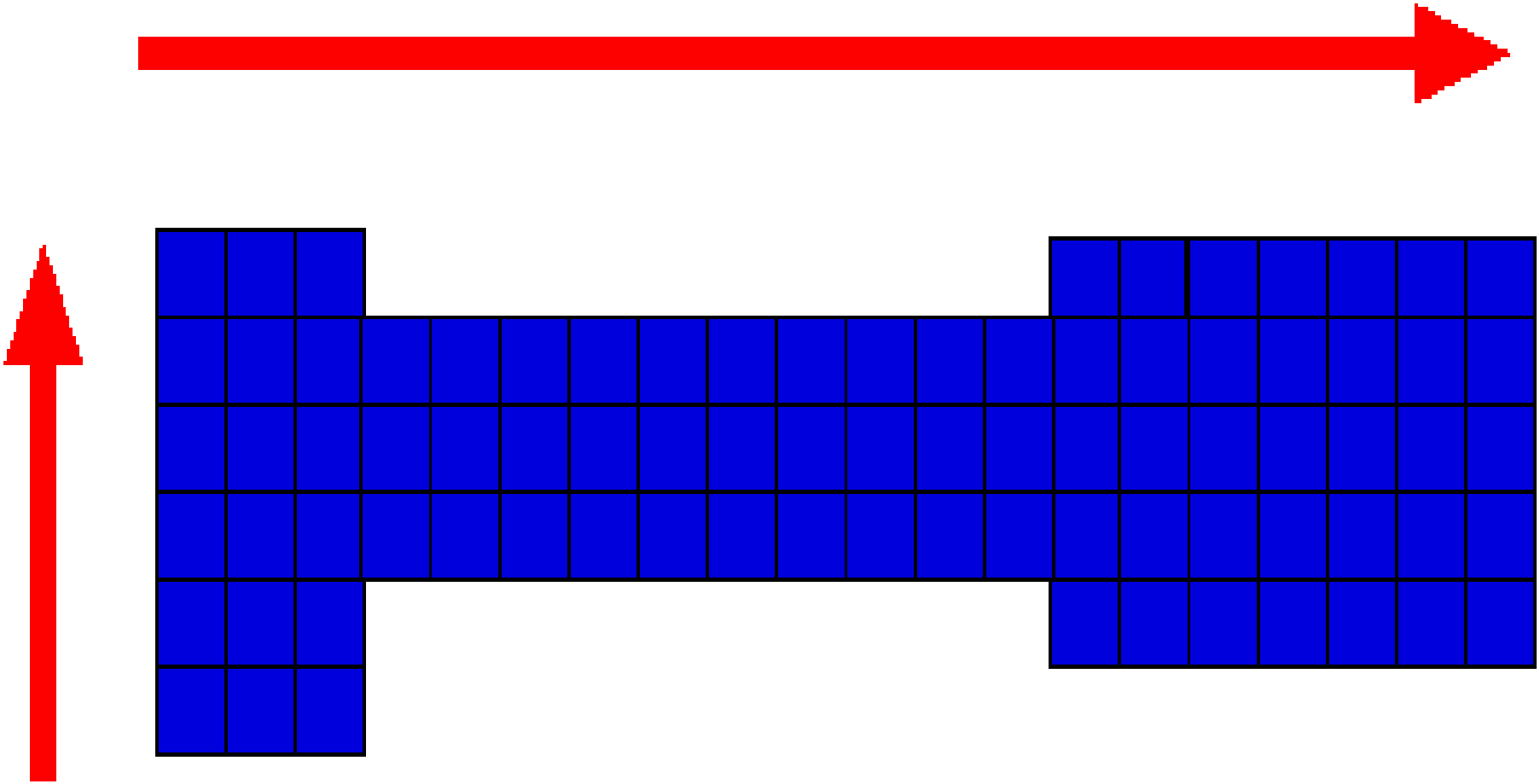
- *Because: the atoms are larger, thus easier to remove an electron*

2. Ionization Energy

As you travel across a period (→) - for representative elements, the 1st ionization energy generally **increases**

- *Because: Greater nuclear charge, thus more attraction and harder to remove the electron*

Ionization Energy Increases With Arrows



Your Turn:

Put these elements in order of decreasing ionization energy

- C N Li F O
- What is the trend?
- Answer: F > O > N > C > Li

3. Electron Affinity

Electron Affinity: the energy change that accompanies the addition of an electron to a neutral atom, forming a negative ion (**anion**)

- Most elements release energy when they gain an electron, making the value of electron affinities negative.

$F\ (g) + e^- \rightarrow F^-\ (g) + 328\ kJ$ EA = -328 kJ/mol

$Be\ (g) + e^- + 240kJ \rightarrow Be^-\ (g)$ EA = +240 kJ/mol

3. Electron Affinity

As you travel down a group (↓):

electron affinities generally decrease: so *electron energy becomes less negative*

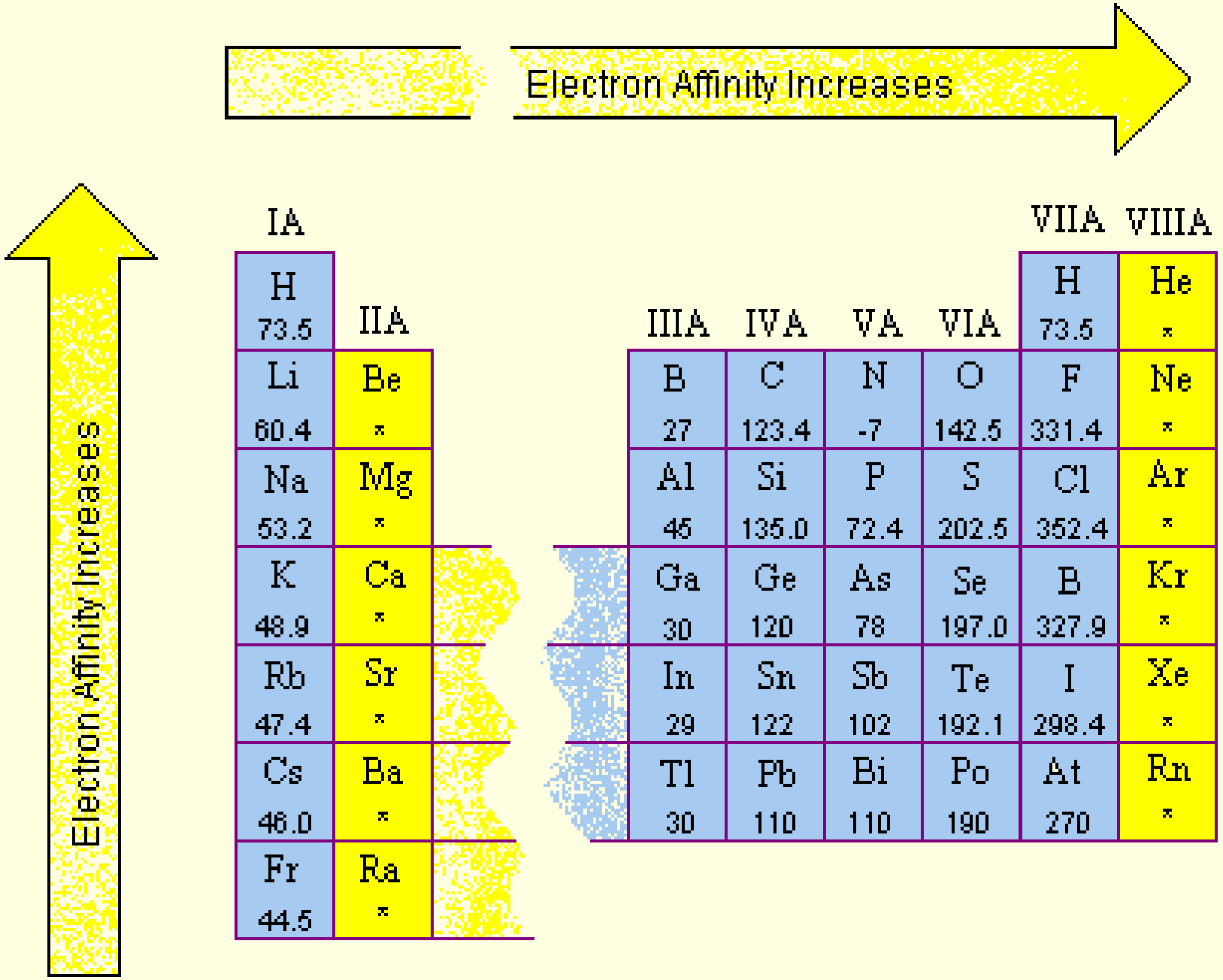
- ***Because:*** *radius is bigger and the pull of the nucleus is not as strong to add e-*
- noble gases do not attract any electrons

(Remember that energy given off is denoted as a negative value!)

3. Electron Affinity

As you travel across a period →: Electron affinities generally **increase** (easier to add e-), so the value becomes more negative

- *Because: radius is smaller and the pull of the nucleus is stronger on e-*


Electron Affinity Increases
Electron Affinity Increases
IA
IIA
IIIA
IVA
VA
VIA
VIIA
VIIIA
H 73.5
Li 60.4
Be *
Na 53.2
Mg *
K 48.9
Ca *
Rb 47.4
Sr *
Cs 46.0
Ba *
Fr 44.5
Ra *
B 27
C 123.4
N -7
O 142.5
Al 46
Si 135.0
P 72.4
S 202.5
Ga 30
Ge 120
As 78
Se 197.0
In 29
Sn 122
Sb 102
Te 192.1
Tl 30
Pb 110
Bi 110
Po 190
H 73.5
F 331.4
Cl 352.4
B 327.9
I 298.4
At 270
He *
Ne *
Ar *
Kr *
Xe *
Rn *

Your Turn:

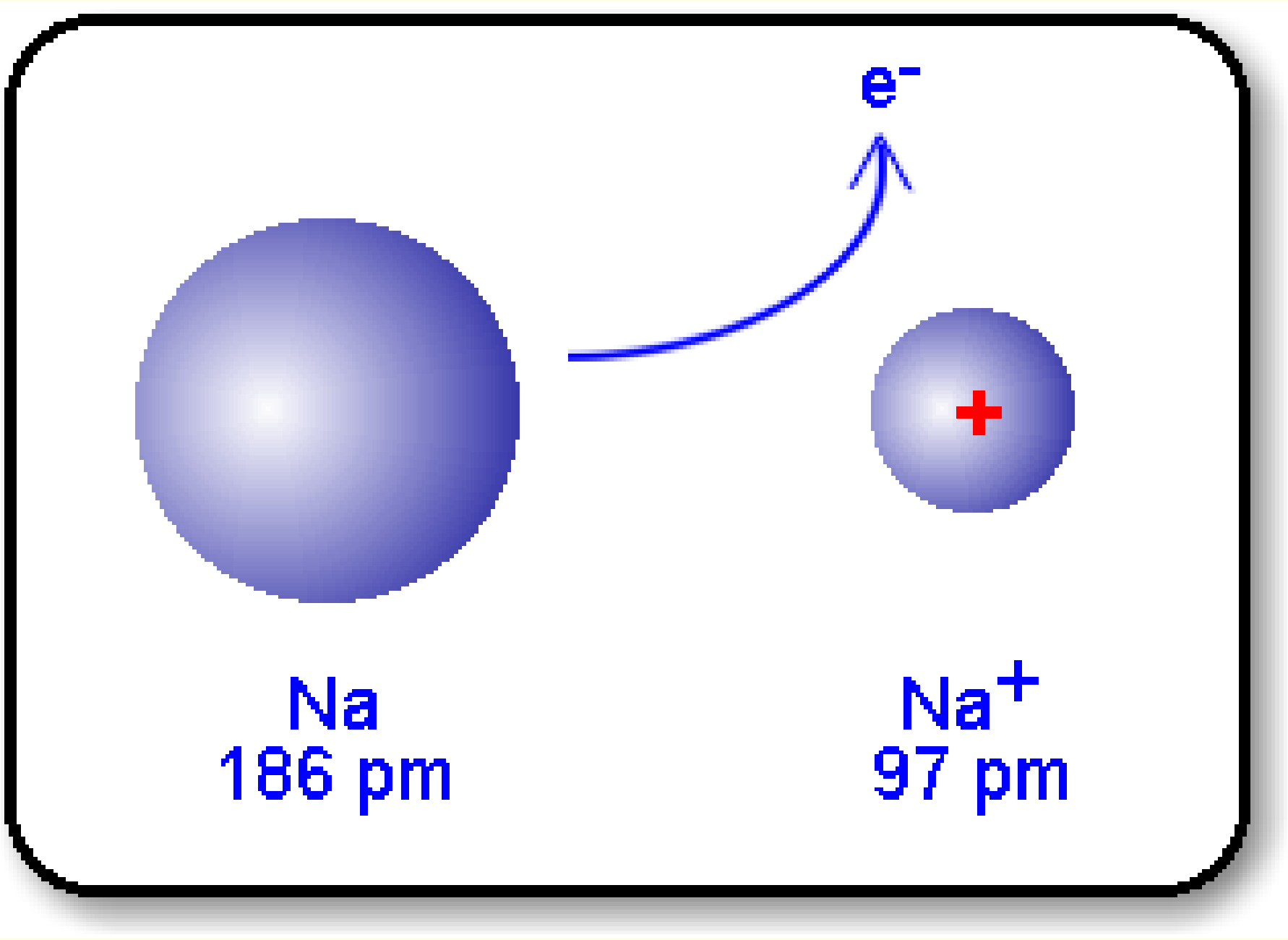
Put these elements in order of increasing electron affinity

- C N Li F O
- What is the trend?
- Answer: Li > C > N > O > F

4. Ionic Radii

Positive ions are **always smaller** than the original atom

- Because = lost electrons in outer energy level


e⁻
Na
186 pm
Na⁺
97 pm

4. Ionic Radii

Negative ions are **always larger** than the original atom

- Because = more electrons with the same nuclear charge holding the atom together

4. Ionic Radii

- As you travel down a group (↓): atomic radii **increase** with both cations and anions
- *Because: radius is getting larger because of more orbitals*

4. Ionic Radii

<u>As you travel across a period →</u>**:**
ionic radii **decrease** in size

- *<u>Because</u>**:** radius is getting smaller because of increased positive charge of nucleus*

Your Turn:

Put these elements in order of decreasing ionic radius

- C N Li F O
- What is the trend?
- Answer: Li > C > N > O > F

5. Electronegativity

Electronegativity: the tendency for an atom to attract electrons to itself when it is chemically combined with another element

- Expressed on the Pauling Electronegativity Scale
- Noble gases do not have electronegativities because they do not participate in many reactions

5. Electronegativity

As you go down a group (↓): **decrease**

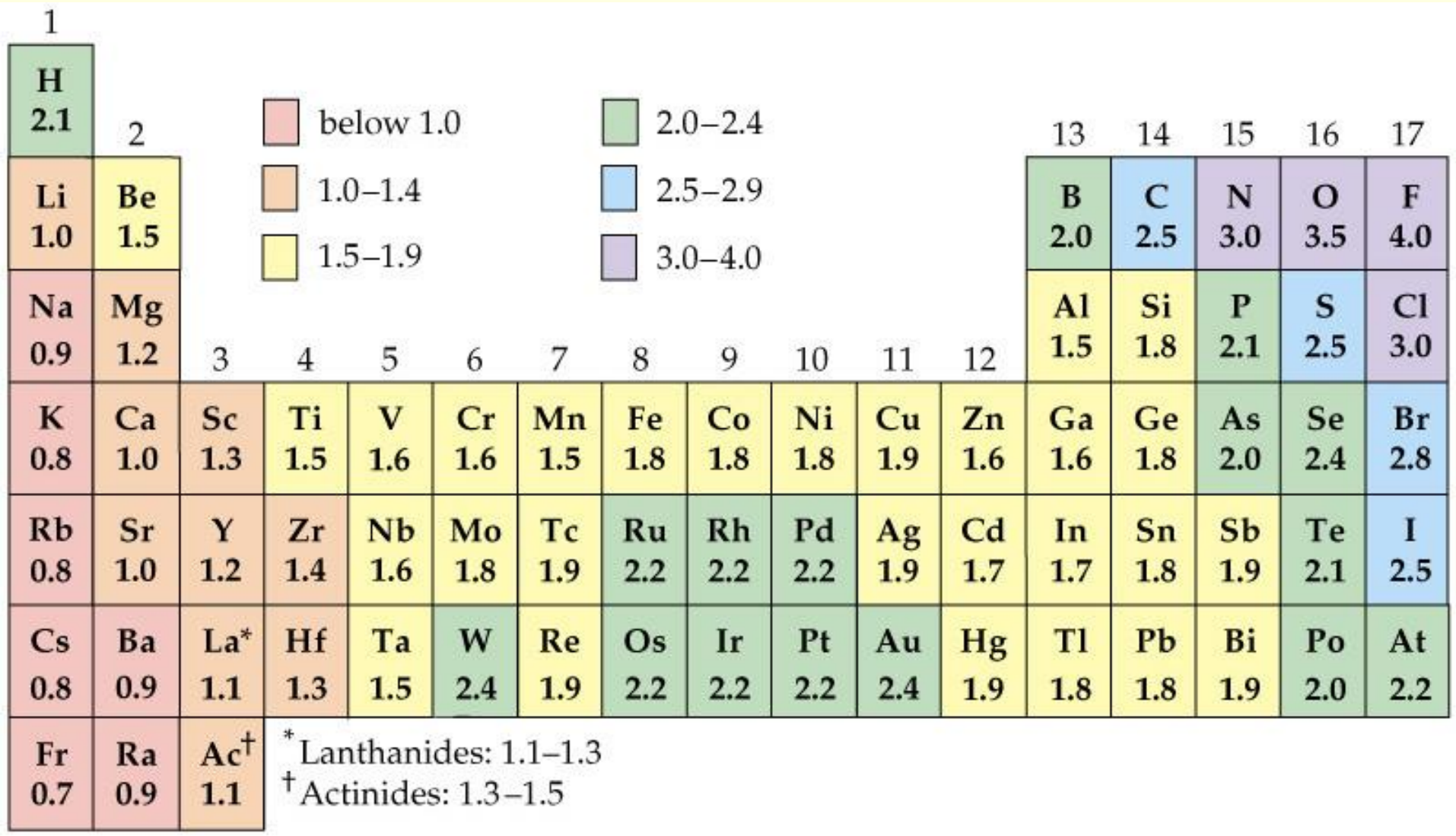
- ***Because:*** *pull by the nucleus is not as strong due to increased layers of orbitals*
- Transition metal electronegativities and other properties are not as regular

5. Electronegativity

As you travel across a period →: **increase**

- ***Because:*** *radii are smaller due to stronger pull by nucleus*

Periodic Table of Electronegativities

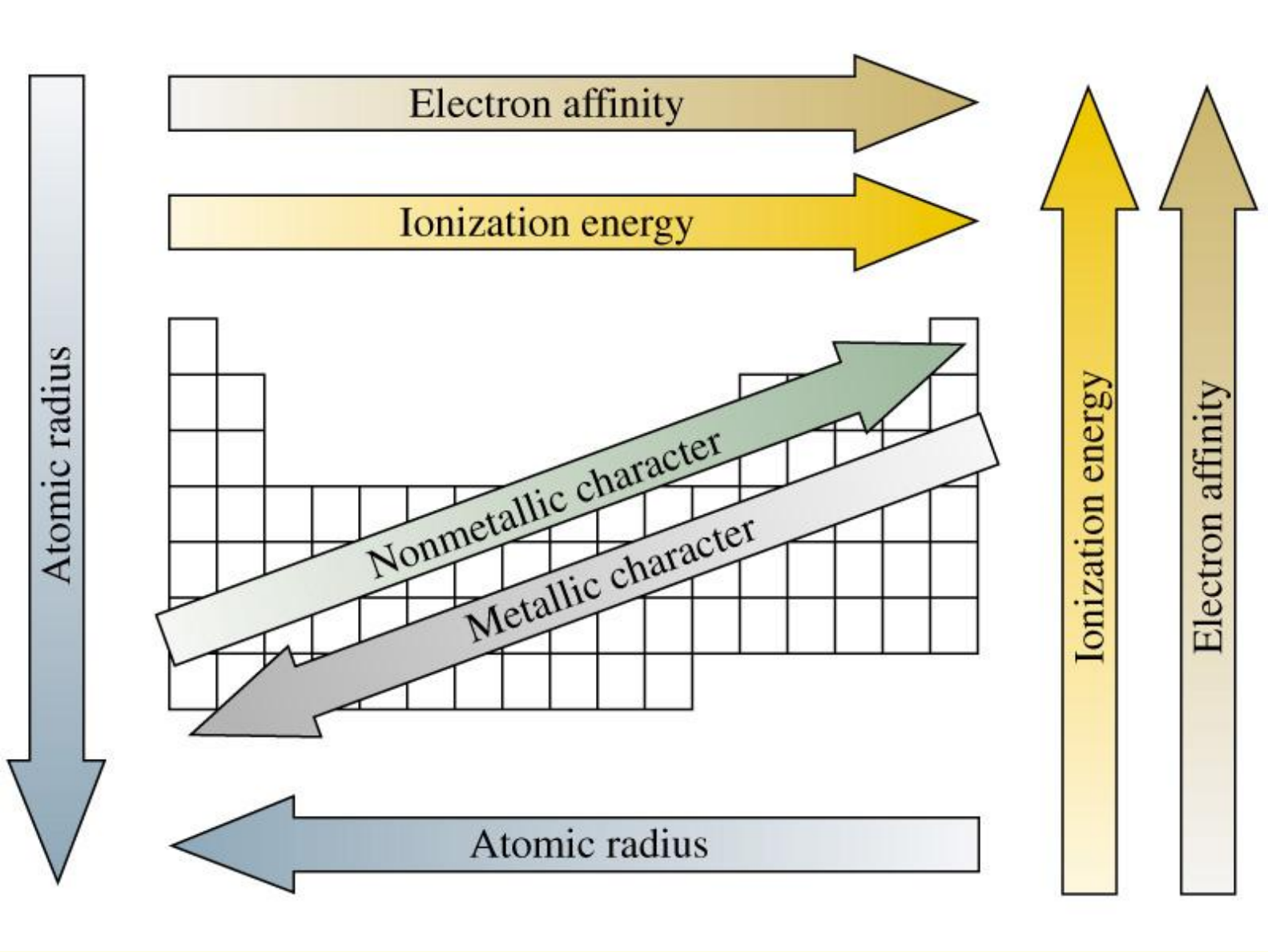


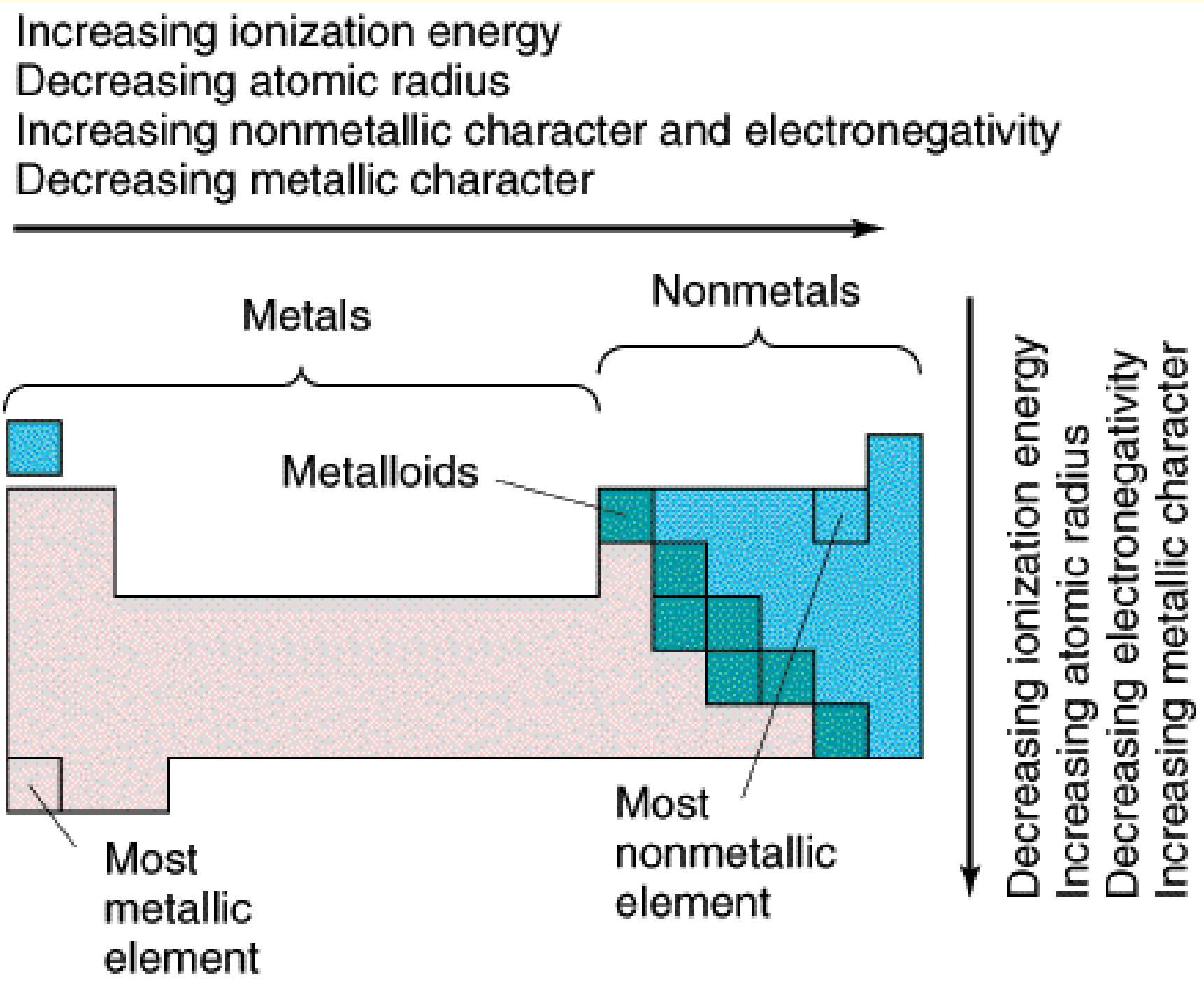
Your Turn:

Put these elements in order of increasing electronegativity

- C N Li F O
- What is the trend?
- Answer: Li > C > N > O > F

Summary of Periodic Trends




Increasing ionization energy
Decreasing atomic radius
Increasing nonmetallic character and electronegativity
Decreasing metallic character
Metals
Nonmetals
Metalloids
Most metallic element
Most nonmetallic element
Decreasing ionization energy
Increasing atomic radius
Decreasing electronegativity
Increasing metallic character