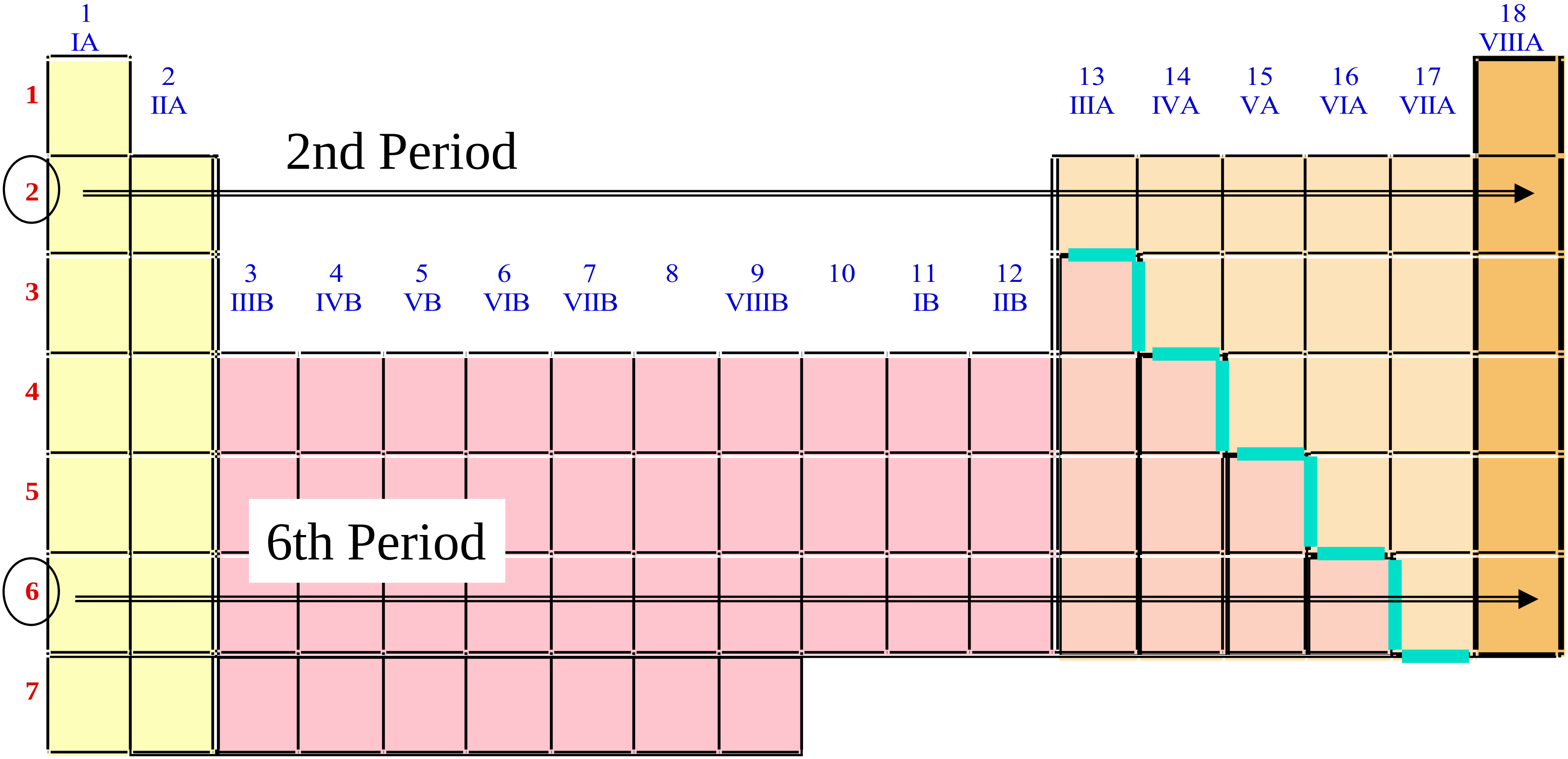
The Periodic Table and Periodic Trends

The properties of the elements exhibit trends and these trends can be predicted with the help of the periodic table. They can also be explained and understood by analyzing the electron configurations of the elements. This is because, elements tend to gain or lose valence electrons to achieve the stable octet formation.

Across the Periodic Table

Periods: Are arranged horizontally across the periodic table (rows 1-7)

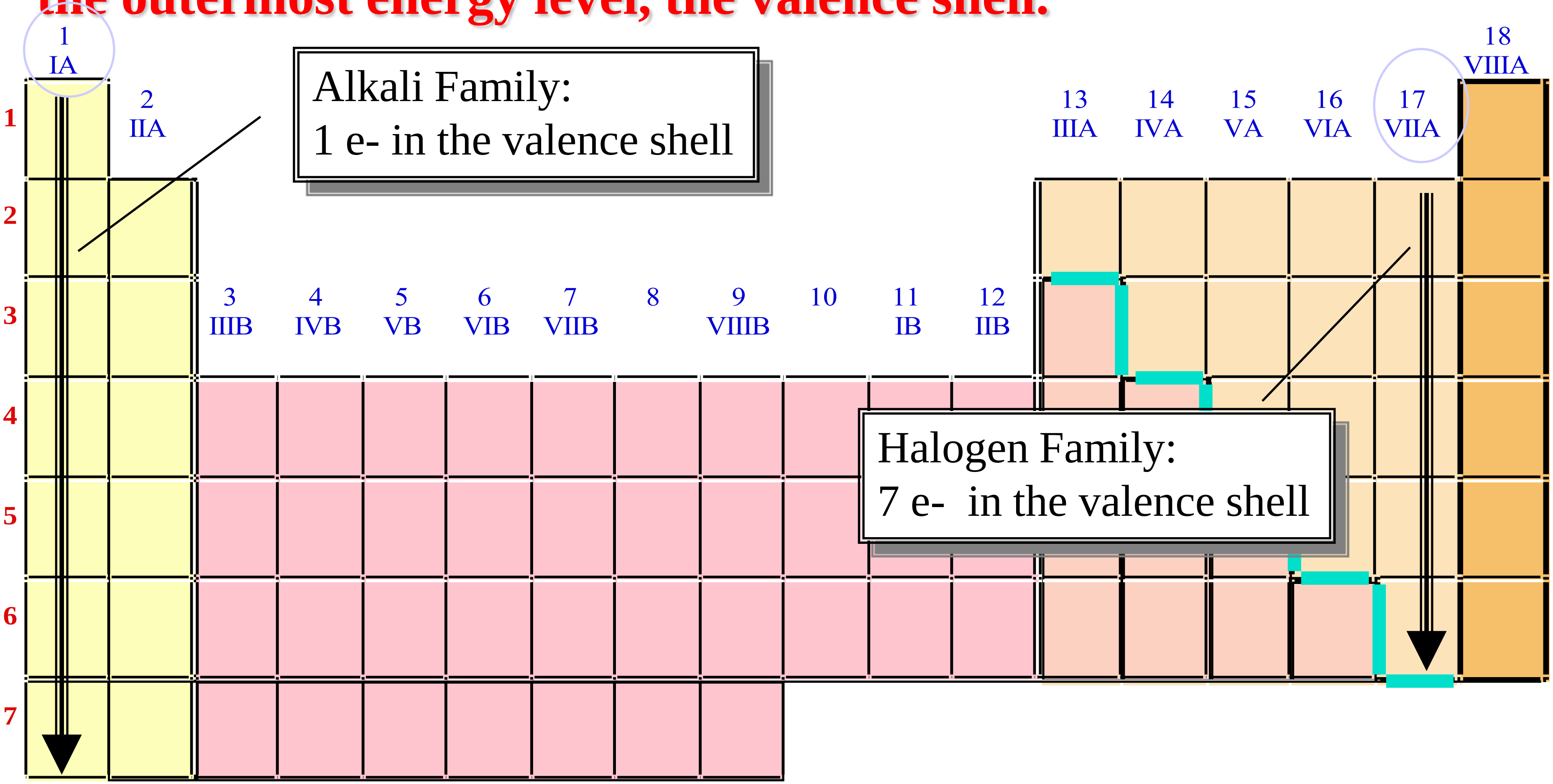
These elements have the same number of valence shells.



Down the Periodic Table

Family or Group: arranged vertically down the periodic table (columns or groups 1- 18)

The elements in each group have the same number of electrons in the outermost energy level, the valence shell.



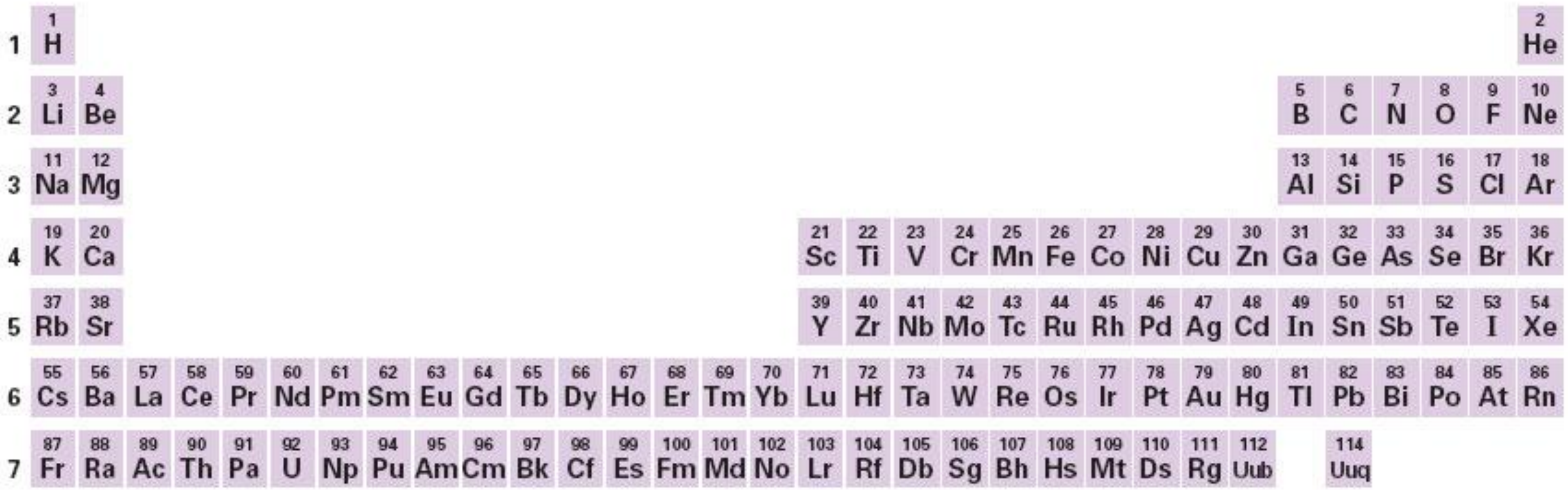
Alkali Family:
1 e- in the valence shell

Halogen Family:
7 e- in the valence shell

The Periodic Law

How is the modern periodic table organized?

- In the modern periodic table, elements are arranged in order of increasing atomic number (since there were problems with Mendeleev’s method).



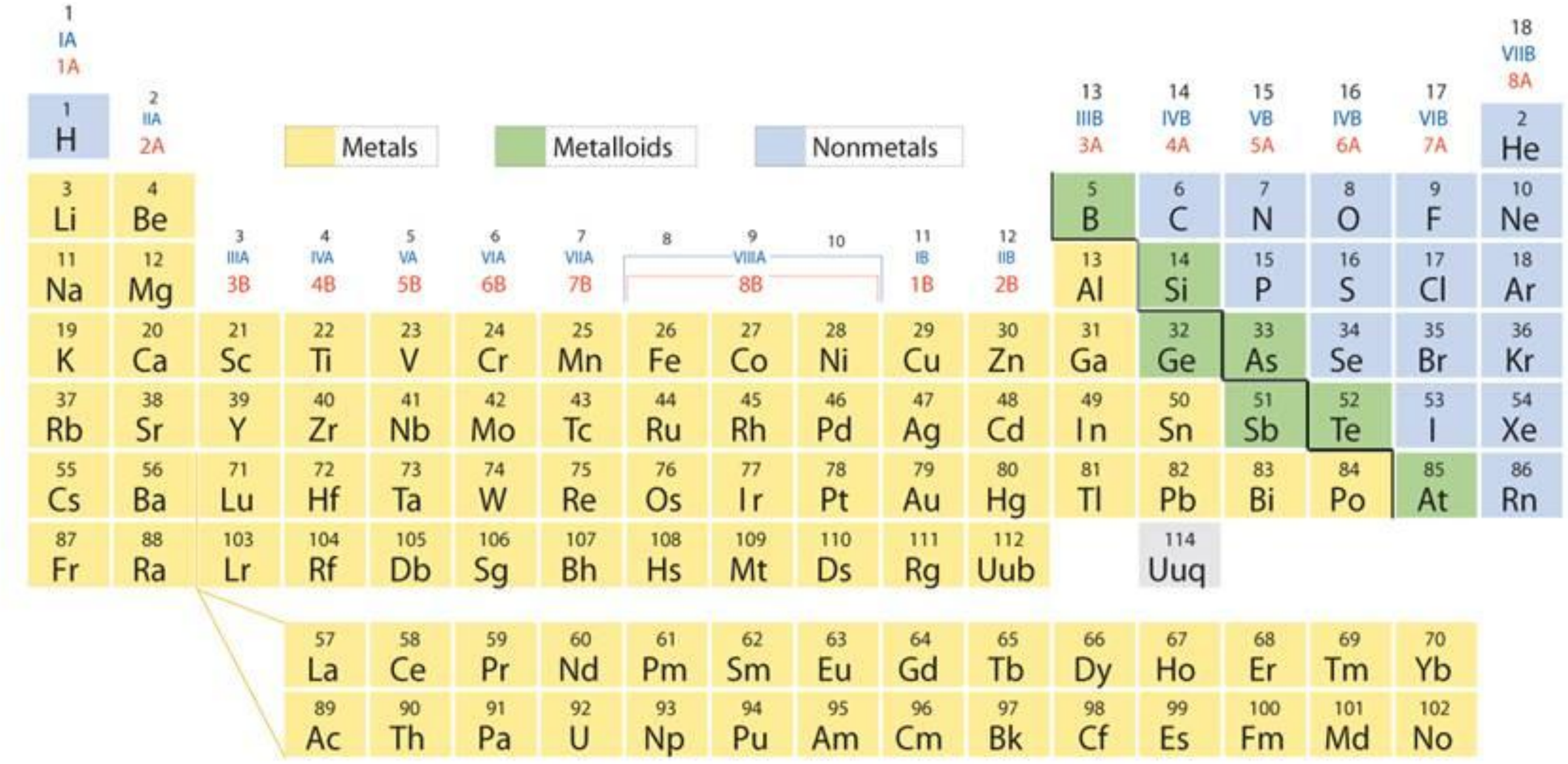
1	1 H																															2 He
2	3 Li	4 Be																									5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg																									13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca															21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 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
6	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	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 Uub		114 Uuq				

The Periodic Law

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

- The properties of the elements within a period change as you move across a period from left to right.
- The pattern of properties within a period repeats as you move from one period to the next.

Metals, Nonmetals, and Metalloids



🟨 Metals

🟩 Metalloids

🟦 Nonmetals

1 IA 1A	2 IIA 2A	3 IIIA 3B	4 IVA 4B	5 VA 5B	6 VIA 6B	7 VIIA 7B	8 VIIIA 8B	9	10	11 IB 1B	12 IIB 2B	13 IIIB 3A	14 IVB 4A	15 VB 5A	16 IVB 6A	17 VIB 7A	18 VIIB 8A
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 Ds	111 Rg	112 Uub		114 Uuq				
			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, Nonmetals, and Metalloids

Metals

- good conductors of heat and electric current.
- 80% of elements are metals.
- Metals have a high lustre, are ductile and malleable.
- Most are grey/silver

🟨 Metals
🟩 Metalloids
🟦 Nonmetals

1 IA 1A	2 IIA 2A	3	4	5	6	7	8	9	10	11	12	13 IIIB 3A	14 IVB 4A	15 VB 5A	16 IVB 6A	17 VIB 7A	18 VIIB 8A
																	2 He
3 Li	4 Be											5 B		7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al		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		33	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		52	53	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	At	86 Rn
87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub		114 Uuq				
		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

- silver, lustrous, malleable, ductile, and good conductors of heat and electricity.

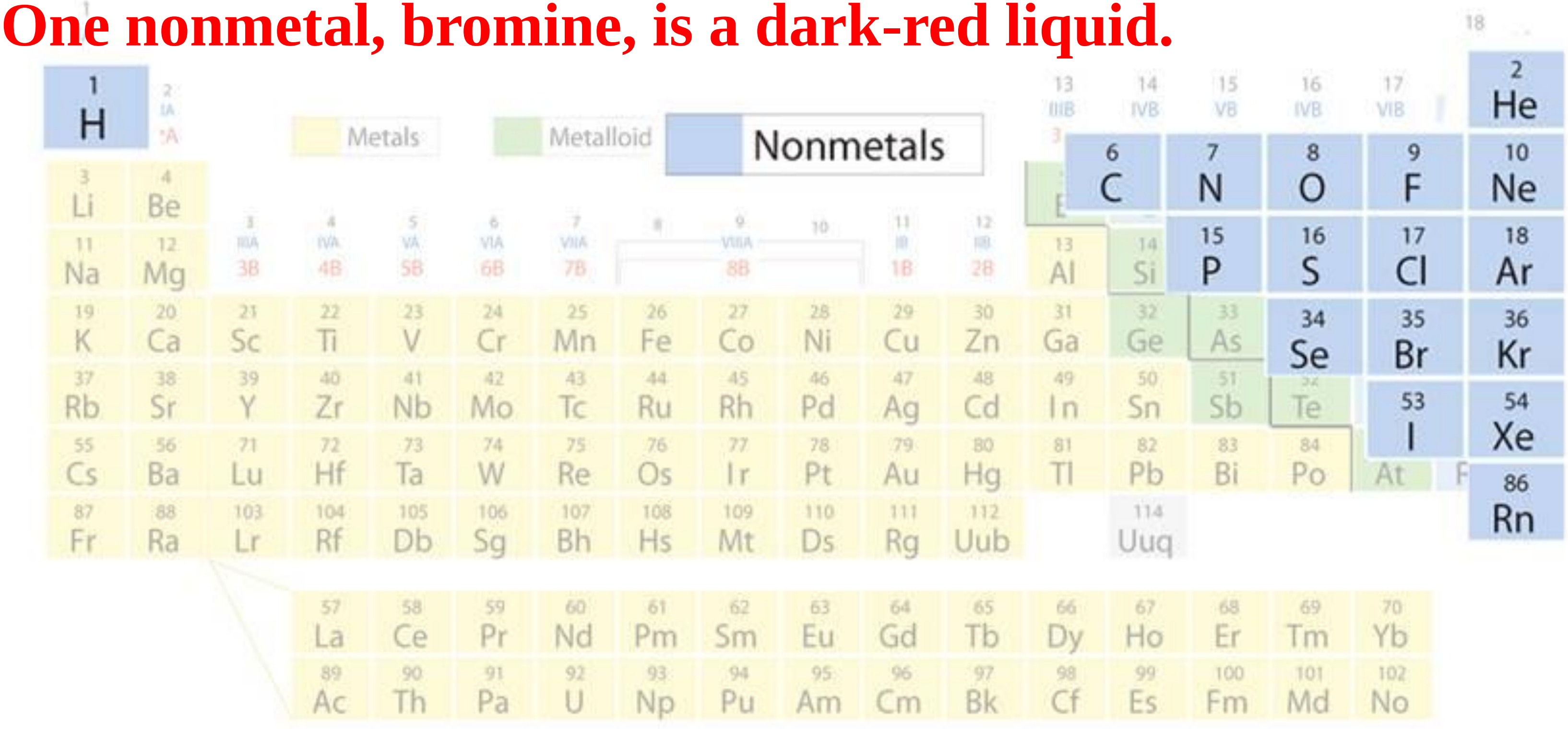
Metals

- **Tend to lose electrons to form compounds.**
- Compounds formed between metals and nonmetals tend to be ionic.
- **Metal oxides (metals reacted with oxygen) tend to be basic.**

Metals, Nonmetals, and Metalloids

–Nonmetals

- In general, nonmetals are poor conductors of heat and electric current.
- Most nonmetals are gases at room temperature.
- Various colours and brittle
- A few nonmetals are solids, such as sulfur and phosphorus.
- One nonmetal, bromine, is a dark-red liquid.



Nonmetals

- Dull, brittle substances that are poor conductors of heat and electricity.
- **Tend to gain electrons in reactions with metals to acquire noble gas configuration.**

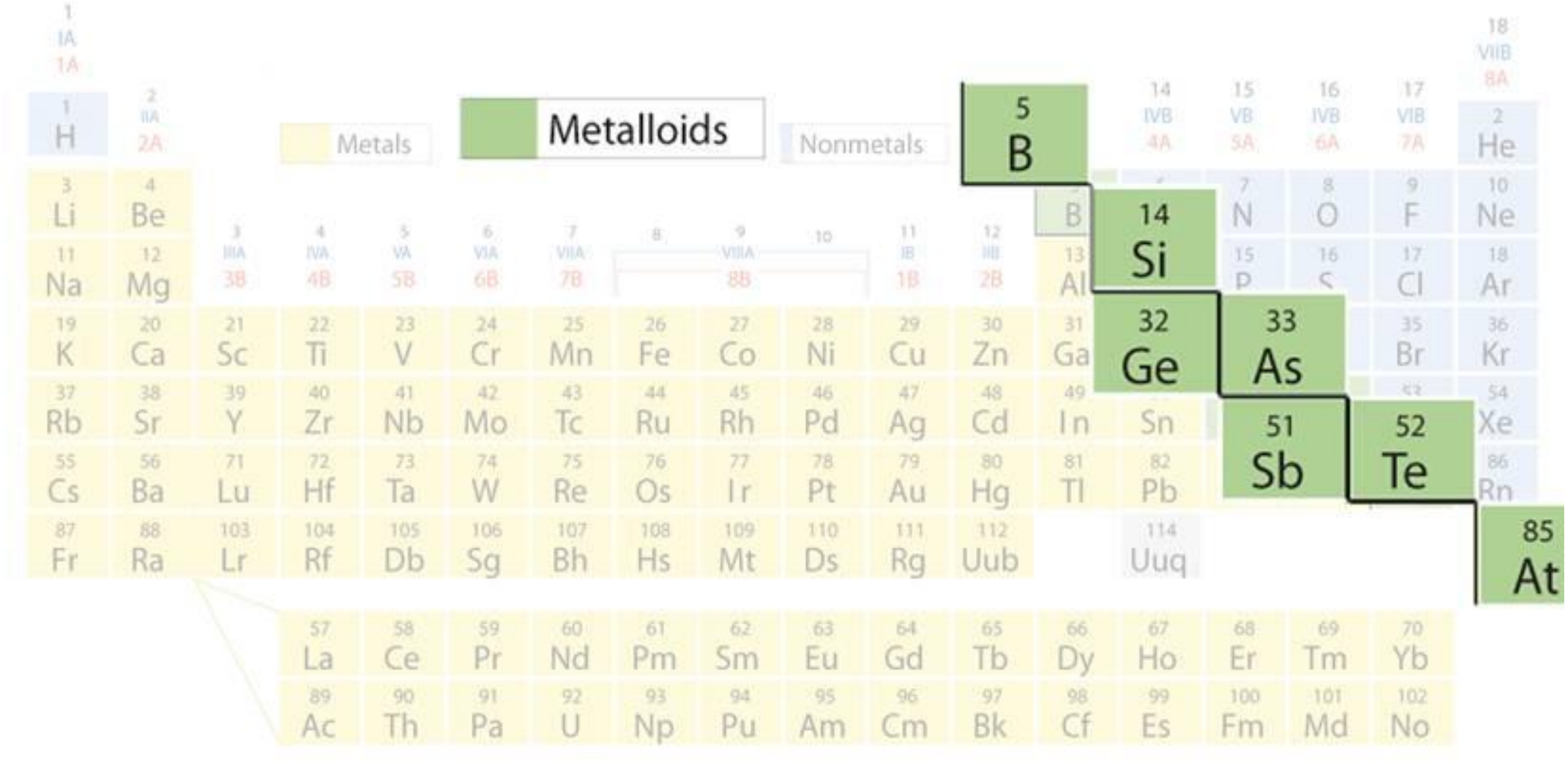
Nonmetals

- Substances containing only nonmetals are molecular compounds.
- **Most nonmetal oxides (non-metal reacted with oxygen) are acidic.**

Metals, Nonmetals, and Metalloids

–Metalloids

- A metalloid generally has properties that are in-between metals and nonmetals.
- Solids, shiny or dull, semi-conductors, brittle and not ductile
- The behavior of a metalloid can be controlled by changing conditions.



Metalloids

- Have some characteristics of metals, some of nonmetals.
- For instance, silicon looks shiny, but is brittle and fairly poor conductor.

Metals, Nonmetals, and Metalloids Examples and Uses

Iron (Fe)
The Gateway Arch in St. Louis, Missouri, is covered in stainless steel containing iron and two other metals, chromium (Cr) and nickel (Ni). The steel is shiny, malleable, and strong. It also resists rusting.

Copper (Cu)
Copper is ductile and second to only silver as a conductor of electric current. The copper used in electrical cables must be 99.99% pure.

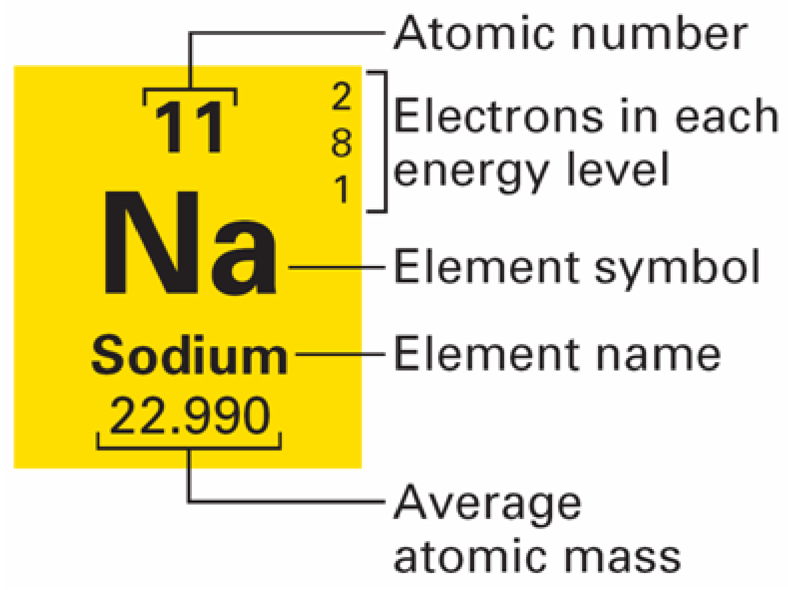
Aluminum (Al)
Aluminum is one of the metals that can be shaped into a thin sheet, or foil. To qualify as a foil, a metal must be no thicker than about 0.15 mm.

Metals, Nonmetals, and Metalloids Examples and Uses

- If a small amount of boron is mixed with silicon, the mixture is a good conductor of electric current. Silicon can be cut into wafers, and used to make computer chips.

Squares in the Periodic Table

- The periodic table displays the symbols and names of the elements, along with information about the structure of their atoms.

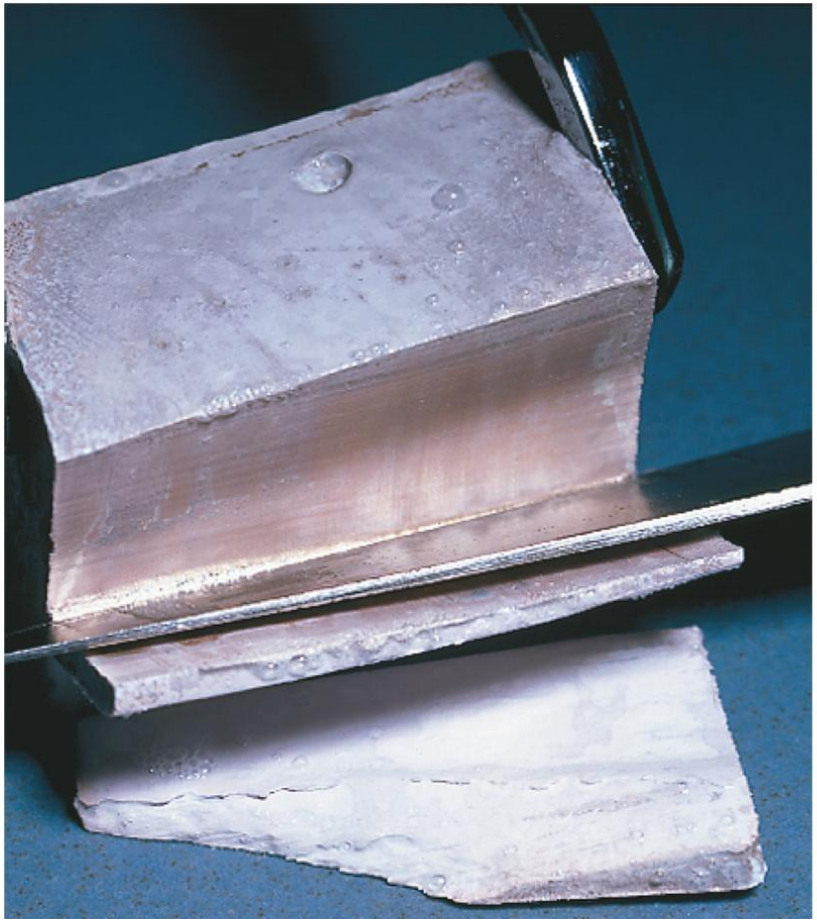


Groups or Families

- Elements in the same column (group) have similar properties

Alkali Metals (Group 1)

- **Soft and reactive solids.**
- **Highly reactive with water and air(oxygen)**
- **Silver-coloured with metallic properties**
- Name comes from Arabic word for ashes.
- **Have one valence electron**
- **Form +1 ions**

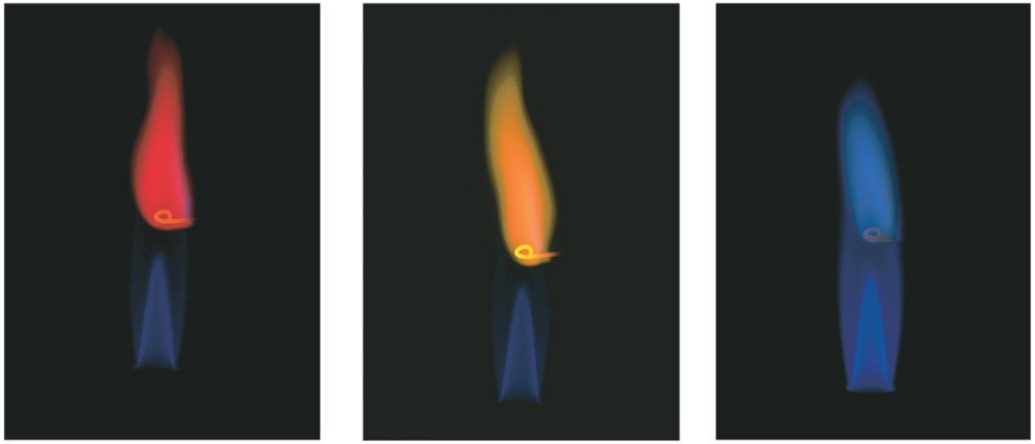


Alkali Metals

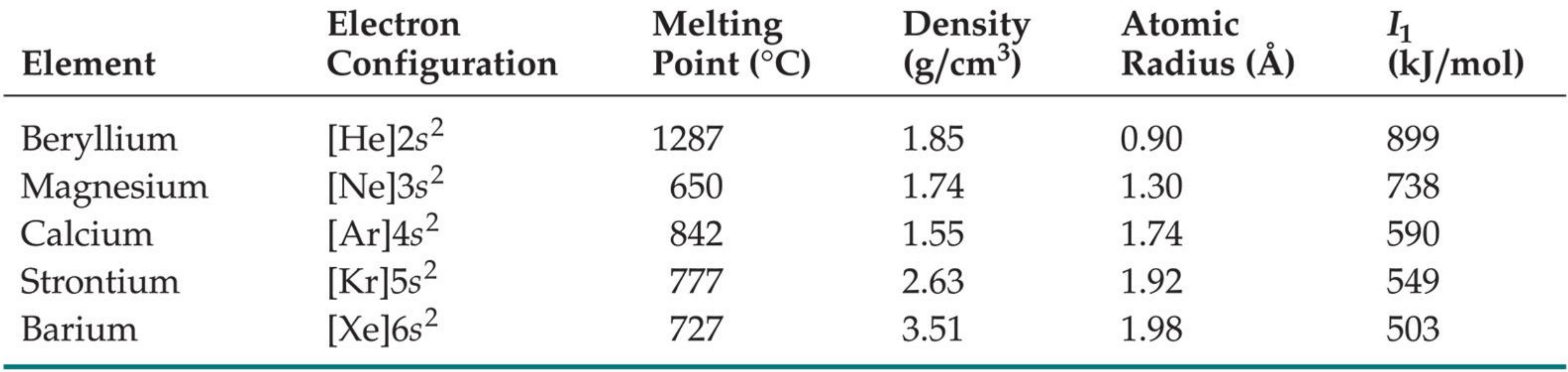
- Alkali metals (except Li) react with oxygen to form peroxides.
- K, Rb, and Cs also form superoxides:

$$K + O_2 \longrightarrow KO_2$$

- Produce bright colors when placed in flame.



Alkaline Earth Metals (Group 2)



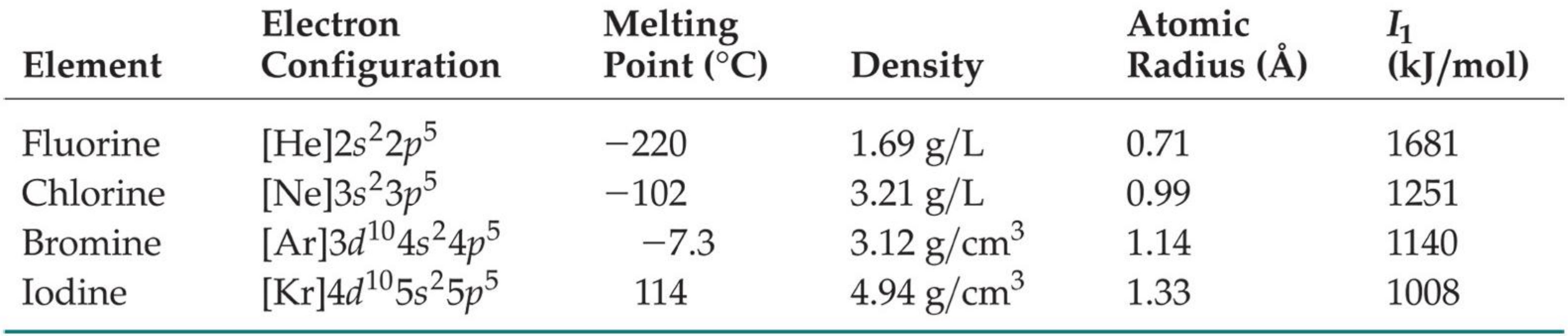
Element	Electron Configuration	Melting Point (°C)	Density (g/cm^3)	Atomic Radius (Å)	I_1 (kJ/mol)
Beryllium	$[He]2s^2$	1287	1.85	0.90	899
Magnesium	$[Ne]3s^2$	650	1.74	1.30	738
Calcium	$[Ar]4s^2$	842	1.55	1.74	590
Strontium	$[Kr]5s^2$	777	2.63	1.92	549
Barium	$[Xe]6s^2$	727	3.51	1.98	503

- **Have higher densities and melting points than alkali metals.**
- **Light, solid and reactive metals.**
- **Have 2 valence electrons and form +2 ions**
- Have low ionization energies, but not as low as alkali metals.

Alkaline Earth Metals

- Be does not react with water, Mg reacts only with steam, but others react readily with water.
- Reactivity tends to increase as go down group.

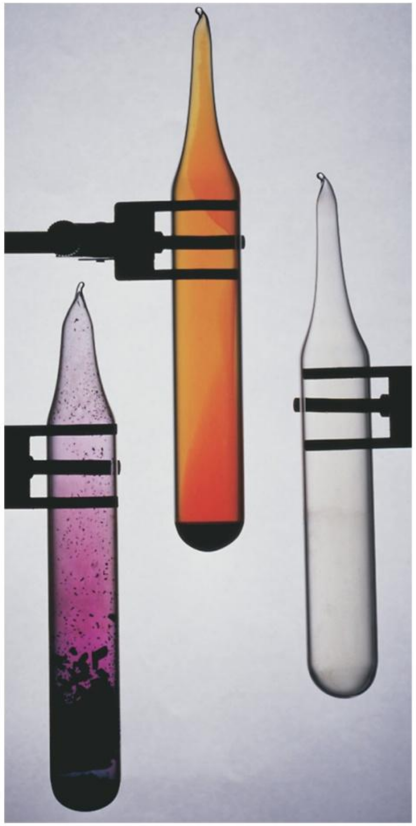
Group 17: Halogens



Element	Electron Configuration	Melting Point (°C)	Density	Atomic Radius (Å)	I_1 (kJ/mol)
Fluorine	$[He]2s^2 2p^5$	−220	1.69 g/L	0.71	1681
Chlorine	$[Ne]3s^2 3p^5$	−102	3.21 g/L	0.99	1251
Bromine	$[Ar]3d^{10} 4s^2 4p^5$	−7.3	$3.12\ g/cm^3$	1.14	1140
Iodine	$[Kr]4d^{10} 5s^2 5p^5$	114	$4.94\ g/cm^3$	1.33	1008

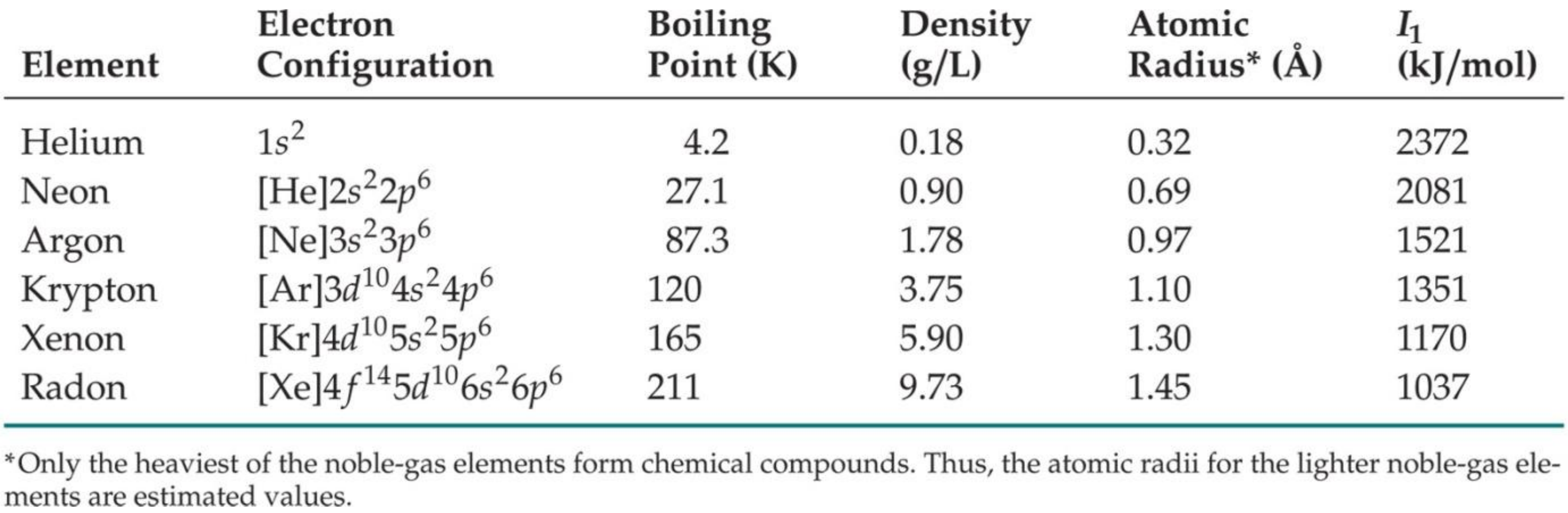
- **Solid, liquid or gas**
- **Non-metallic, not lustrous, nonconductors and very reactive**
- **Have 7 valence electrons and form -1 ions**
- Name comes from the Greek *halos* and *gennao*: “salt formers”

Group 17: Halogens



- Large, negative electron affinities
  - Therefore, tend to oxidize other elements easily
- React directly with metals to form metal halides
- Chlorine added to water supplies to serve as disinfectant

Group 18: Noble Gases



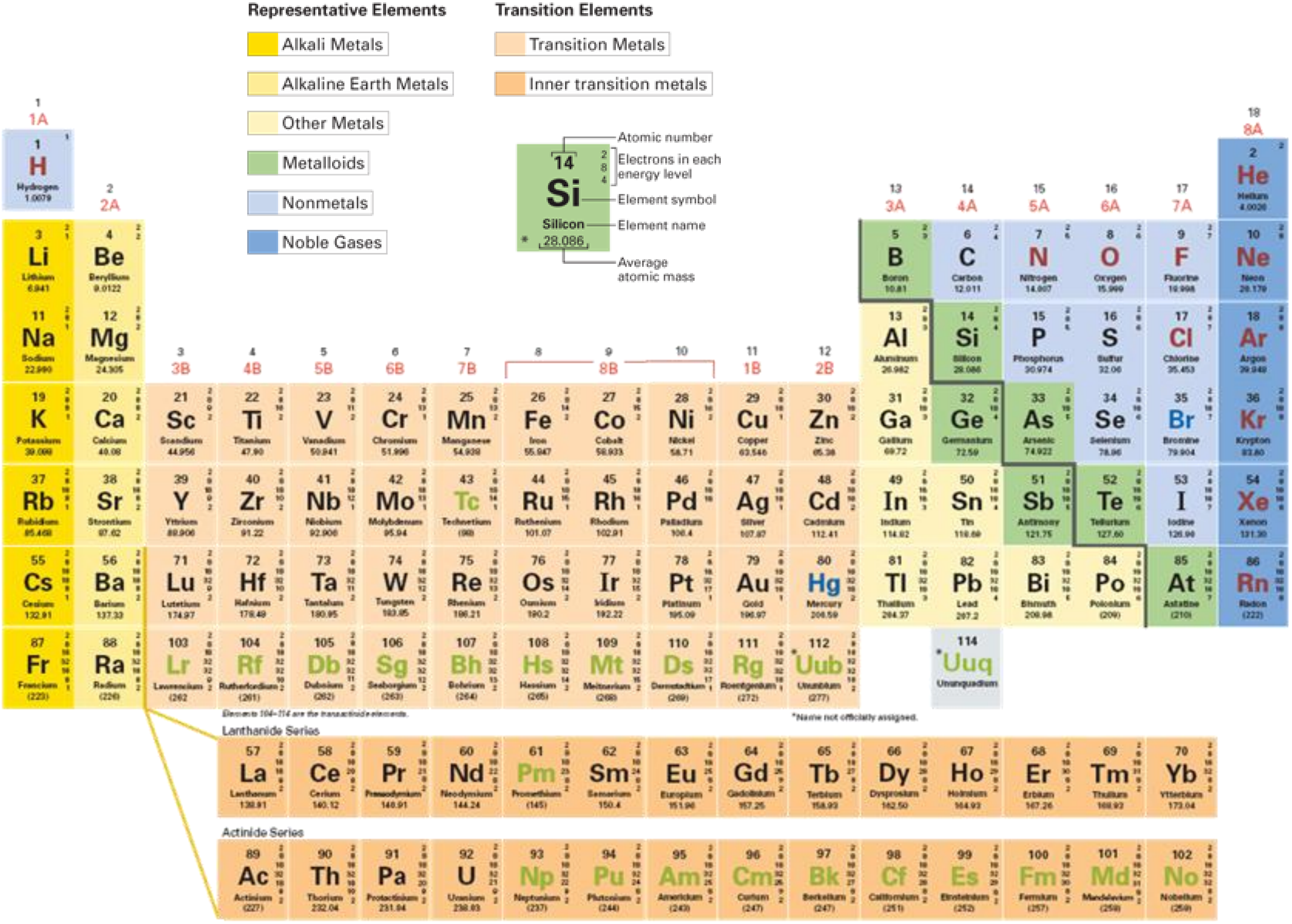
Element	**Electron Configuration**	**Boiling Point (K)**	**Density (g/L)**	**Atomic Radius* (Å)**	**I_1 (kJ/mol)**
Helium	$1s^2$	4.2	0.18	0.32	2372
Neon	$[He]2s^22p^6$	27.1	0.90	0.69	2081
Argon	$[Ne]3s^23p^6$	87.3	1.78	0.97	1521
Krypton	$[Ar]3d^{10}4s^24p^6$	120	3.75	1.10	1351
Xenon	$[Kr]4d^{10}5s^25p^6$	165	5.90	1.30	1170
Radon	$[Xe]4f^{14}5d^{10}6s^26p^6$	211	9.73	1.45	1037

*Only the heaviest of the noble-gas elements form chemical compounds. Thus, the atomic radii for the lighter noble-gas elements are estimated values.

- **Gases, low melting and boiling points, nonreactive**
- **Have 8 valence electrons and rarely form ions**
- Astronomical ionization energies
- Positive electron affinities
  - Therefore, relatively unreactive
- **Monatomic gases**

Group 18: Noble Gases

- Xe forms three compounds:
  - XeF_2
  - XeF_4 (at right)
  - XeF_6
- Kr forms only one stable compound:
  - KrF_2
- The unstable HArF was synthesized in 2000.



Representative Elements

🟨 Alkali Metals

🟨 Alkaline Earth Metals

🟨 Other Metals

🟩 Metalloids

🟦 Nonmetals

🟦 Noble Gases

Transition Elements

🟧 Transition Metals

🟧 Inner transition metals

14	Atomic number
2 8 4	Electrons in each energy level
Si	Element symbol
Silicon	Element name
* 28.086	Average atomic mass

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H Hydrogen 1.0079 1																	2 He Helium 4.0026 2
3 Li Lithium 6.941 2 1	4 Be Beryllium 9.0122 2 2											5 B Boron 10.81 2 3	6 C Carbon 12.011 2 4	7 N Nitrogen 14.007 2 5	8 O Oxygen 15.999 2 6	9 F Fluorine 18.998 2 7	10 Ne Neon 20.179 2 8
11 Na Sodium 22.990 2 8 1	12 Mg Magnesium 24.305 2 8 2											13 Al Aluminum 26.982 2 8 3	14 Si Silicon 28.086 2 8 4	15 P Phosphorus 30.974 2 8 5	16 S Sulfur 32.06 2 8 6	17 Cl Chlorine 35.453 2 8 7	18 Ar Argon 39.948 2 8 8
19 K Potassium 39.098 2 8 8 1	20 Ca Calcium 40.08 2 8 8 2	21 Sc Scandium 44.956 2 8 9 2	22 Ti Titanium 47.90 2 8 10 2	23 V Vanadium 50.941 2 8 11 2	24 Cr Chromium 51.996 2 8 13 1	25 Mn Manganese 54.938 2 8 13 2	26 Fe Iron 55.847 2 8 14 2	27 Co Cobalt 58.933 2 8 15 2	28 Ni Nickel 58.71 2 8 16 2	29 Cu Copper 63.546 2 8 18 1	30 Zn Zinc 65.38 2 8 18 2	31 Ga Gallium 69.72 2 8 18 3	32 Ge Germanium 72.59 2 8 18 4	33 As Arsenic 74.922 2 8 18 5	34 Se Selenium 78.96 2 8 18 6	35 Br Bromine 79.904 2 8 18 7	36 Kr Krypton 83.80 2 8 18 8
37 Rb Rubidium 85.468 2 8 18 8 1	38 Sr Strontium 87.62 2 8 18 8 2	39 Y Yttrium 88.906 2 8 18 9 2	40 Zr Zirconium 91.22 2 8 18 10 2	41 Nb Niobium 92.906 2 8 18 12 1	42 Mo Molybdenum 95.94 2 8 18 13 1	43 Tc Technetium (98) 2 8 18 14 1	44 Ru Ruthenium 101.07 2 8 18 15 1	45 Rh Rhodium 102.91 2 8 18 16 1	46 Pd Palladium 106.4 2 8 18 18	47 Ag Silver 107.87 2 8 18 18 1	48 Cd Cadmium 112.41 2 8 18 18 2	49 In Indium 114.82 2 8 18 18 3	50 Sn Tin 118.69 2 8 18 18 4	51 Sb Antimony 121.75 2 8 18 18 5	52 Te Tellurium 127.60 2 8 18 18 6	53 I Iodine 126.90 2 8 18 18 7	54 Xe Xenon 131.30 2 8 18 18 8
55 Cs Cesium 132.91 2 8 18 18 8 1	56 Ba Barium 137.33 2 8 18 18 8 2	71 Lu Lutetium 174.97 2 8 18 32 9 2	72 Hf Hafnium 178.49 2 8 18 32 10 2	73 Ta Tantalum 180.95 2 8 18 32 11 2	74 W Tungsten 183.85 2 8 18 32 12 2	75 Re Rhenium 186.21 2 8 18 32 13 2	76 Os Osmium 190.2 2 8 18 32 14 2	77 Ir Iridium 192.22 2 8 18 32 15 2	78 Pt Platinum 195.09 2 8 18 32 17 1	79 Au Gold 196.97 2 8 18 32 18 1	80 Hg Mercury 200.59 2 8 18 32 18 2	81 Tl Thallium 204.37 2 8 18 32 18 3	82 Pb Lead 207.2 2 8 18 32 18 4	83 Bi Bismuth 208.98 2 8 18 32 18 5	84 Po Polonium (209) 2 8 18 32 18 6	85 At Astatine (210) 2 8 18 32 18 7	86 Rn Radon (222) 2 8 18 32 18 8
87 Fr Francium (223) 2 8 18 32 18 8 1	88 Ra Radium (226) 2 8 18 32 18 8 2	103 Lr Lawrencium (262 2 8 18 32 32 9 2	104 Rf Rutherfordium (261) 2 8 18 32 32 10 2	105 Db Dubnium (262) 2 8 18 32 32 11 2	106 Sg Seaborgium (263) 2 8 18 32 32 12 2	107 Bh Bohrium (264) 2 8 18 32 32 13 2	108 Hs Hassium (265) 2 8 18 32 32 14 2	109 Mt Meitnerium (268) 2 8 18 32 32 15 2	110 Ds Darmstadtium (269) 2 8 18 32 32 17 1	111 Rg Roentgenium (272) 2 8 18 32 32 18 1	112 *Uub Ununbium (277) 2 8 18 32 32 18 2		114 *Uuq Ununquadium				

Elements 104–114 are the transactinide elements.

*Name not officially assigned.

Lanthanide Series

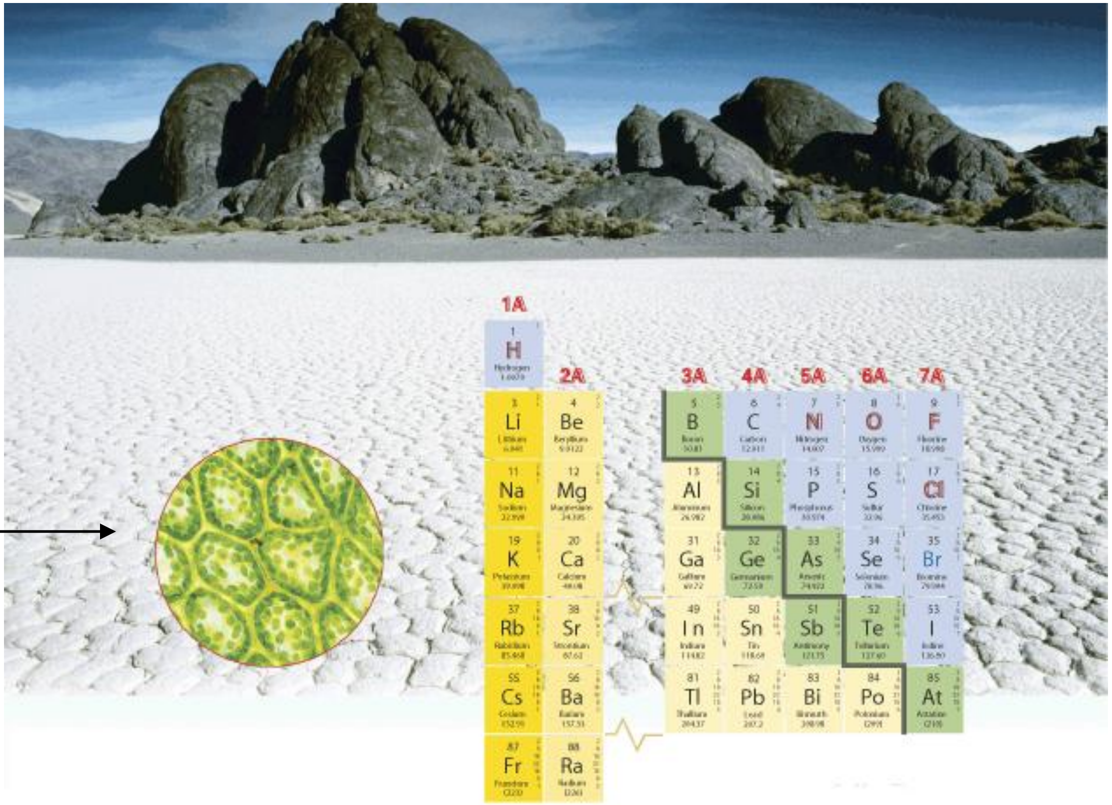
57 La Lanthanum 138.91 2 8 18 18 9 2	58 Ce Cerium 140.12 2 8 18 20 8 2	59 Pr Praseodymium 140.91 2 8 18 21 8 2	60 Nd Neodymium 144.24 2 8 18 22 8 2	61 Pm Promethium (145) 2 8 18 23 8 2	62 Sm Samarium 150.4 2 8 18 24 8 2	63 Eu Europium 151.96 2 8 18 25 8 2	64 Gd Gadolinium 157.25 2 8 18 25 9 2	65 Tb Terbium 158.93 2 8 18 27 8 2	66 Dy Dysprosium 162.50 2 8 18 28 8 2	67 Ho Holmium 164.93 2 8 18 29 8 2	68 Er Erbium 167.26 2 8 18 30 8 2	69 Tm Thulium 168.93 2 8 18 31 8 2	70 Yb Ytterbium 173.04 2 8 18 32 8 2

Actinide Series

89 Ac Actinium (227) 2 8 18 32 18 9 2	90 Th Thorium 232.04 2 8 18 32 18 10 2	91 Pa Protactinium 231.04 2 8 18 32 20 9 2	92 U Uranium 238.03 2 8 18 32 21 9 2	93 Np Neptunium (237) 2 8 18 32 22 9 2	94 Pu Plutonium (244) 2 8 18 32 24 8 2	95 Am Americium (243) 2 8 18 32 25 8 2	96 Cm Curium (247) 2 8 18 32 25 9 2	97 Bk Berkelium (247) 2 8 18 32 27 8 2	98 Cf Californium (251) 2 8 18 32 28 8 2	99 Es Einsteinium (252) 2 8 18 32 29 8 2	100 Fm Fermium (257) 2 8 18 32 30 8 2	101 Md Mendelevium (258) 2 8 18 32 31 8 2	102 No Nobelium (259) 2 8 18 32 32 8 2

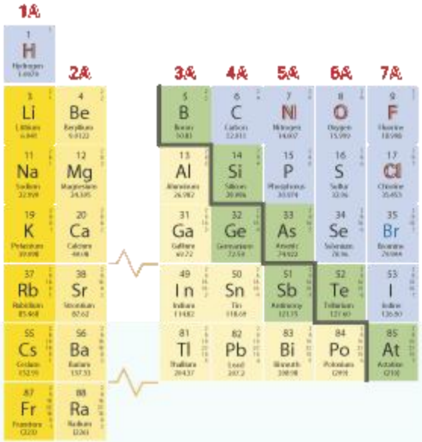
Representative Elements – Examples and Uses

Magnesium This magnified view of a leaf shows the green structures where light energy is changed into chemical energy. The compound chlorophyll, which contains magnesium, absorbs the light.



Sodium When salt lakes evaporate, they form salt pans like this one in Death Valley, California. The main salt in a salt pan is sodium chloride.

Representative Elements



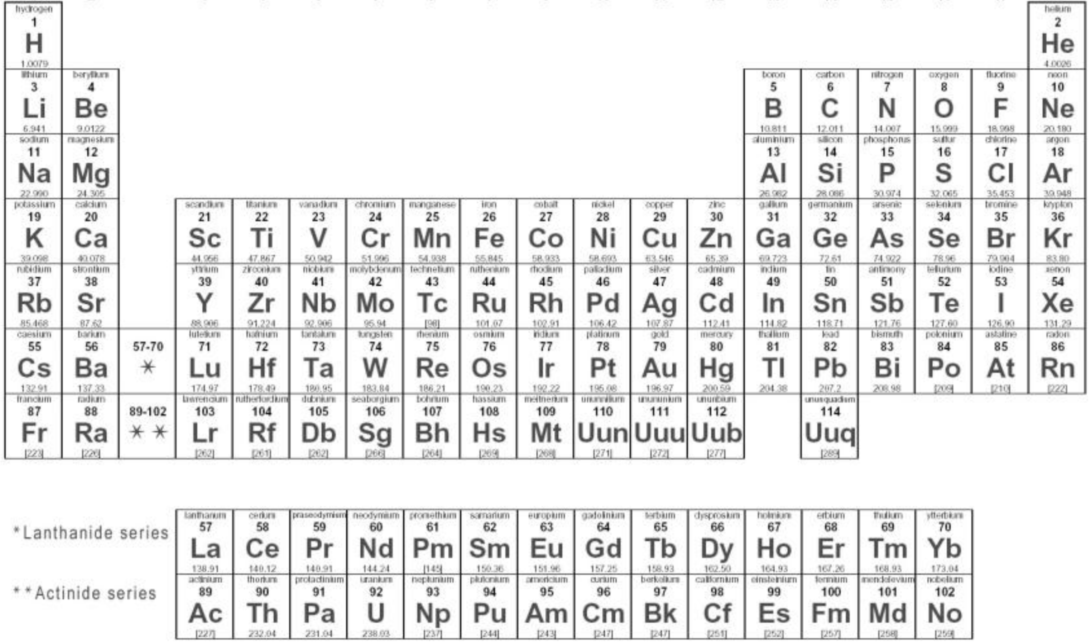
1A	2A	3A	4A	5A	6A	7A
1 H						
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl
19 K	20 Ca	31 Ga	32 Ge	33 As	34 Se	35 Br
37 Rb	38 Sr	49 In	50 Sn	51 Sb	52 Te	53 I
55 Cs	56 Ba	81 Tl	82 Pb	83 Bi	84 Po	85 At
87 Fr	88 Ra					

Arsenic This bright red ore is a major source of arsenic in Earth's crust. It contains a compound of arsenic and sulfur.

Sulfur These scientists are sampling gases being released from a volcano through a vent called a fumarole. The yellow substance is sulfur.

Periodic Trends

- You will learn how properties (such as atomic size) are related to the location of elements in the periodic table.



hydrogen 1 H																		helium 2 He
lithium 3 Li	beryllium 4 Be												boron 5 B	carbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	neon 10 Ne
sodium 11 Na	magnesium 12 Mg												aluminium 13 Al	silicon 14 Si	phosphorus 15 P	sulfur 16 S	chlorine 17 Cl	argon 18 Ar
potassium 19 K	calcium 20 Ca		scandium 21 Sc	titanium 22 Ti	vanadium 23 V	chromium 24 Cr	manganese 25 Mn	iron 26 Fe	cobalt 27 Co	nickel 28 Ni	copper 29 Cu	zinc 30 Zn	gallium 31 Ga	germanium 32 Ge	arsenic 33 As	selenium 34 Se	bromine 35 Br	krypton 36 Kr
rubidium 37 Rb	strontium 38 Sr		yttrium 39 Y	zirconium 40 Zr	niobium 41 Nb	molybdenum 42 Mo	technetium 43 Tc	ruthenium 44 Ru	rhodium 45 Rh	palladium 46 Pd	silver 47 Ag	cadmium 48 Cd	indium 49 In	tin 50 Sn	antimony 51 Sb	tellurium 52 Te	iodine 53 I	xenon 54 Xe
caesium 55 Cs	barium 56 Ba	57-70 *	lutetium 71 Lu	hafnium 72 Hf	tantalum 73 Ta	tungsten 74 W	rhenium 75 Re	osmium 76 Os	iridium 77 Ir	platinum 78 Pt	gold 79 Au	mercury 80 Hg	thallium 81 Tl	lead 82 Pb	bismuth 83 Bi	polonium 84 Po	astatine 85 At	radon 86 Rn
francium 87 Fr	radium 88 Ra	89-102 * *	lawrencium 103 Lr	rutherfordium 104 Rf	dubnium 105 Db	seaborgium 106 Sg	bohrium 107 Bh	hassium 108 Hs	meitnerium 109 Mt	ununnilium 110 Uun	unununium 111 Uuu	ununbium 112 Uub		ununquadium 114 Uuq				

*Lanthanide series	lanthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	neodymium 60 Nd	promethium 61 Pm	samarium 62 Sm	europium 63 Eu	gadolinium 64 Gd	terbium 65 Tb	dysprosium 66 Dy	holmium 67 Ho	erbium 68 Er	thulium 69 Tm	ytterbium 70 Yb
* *Actinide series	actinium 89 Ac	thorium 90 Th	protactinium 91 Pa	uranium 92 U	neptunium 93 Np	plutonium 94 Pu	americium 95 Am	curium 96 Cm	berkelium 97 Bk	californium 98 Cf	einsteinium 99 Es	fermium 100 Fm	mendelevium 101 Md	nobelium 102 No

Orbitals in Multielectron Atoms

- Electrons are attracted to the nucleus but also repelled by each other.
- Repulsion from other electrons reduces the attraction to the nucleus and this is called the **shielding or screening effect**. It increases as you go down a group.
- The attraction the electrons have for the nucleus is the **nuclear charge**. It increases as you go from left to right across a row.
- **Effective nuclear charge**: the net nuclear charge felt by an electron after shielding from other electrons in the atom is taken into account.

ALL Periodic Table Trends

- Influenced by three factors:

  1. Energy Level - higher energy levels are further away from the nucleus. Less pull on outer electrons.

  2. Charge on nucleus (# protons)
    - More charge pulls electrons in closer. (+ and – attract each other)

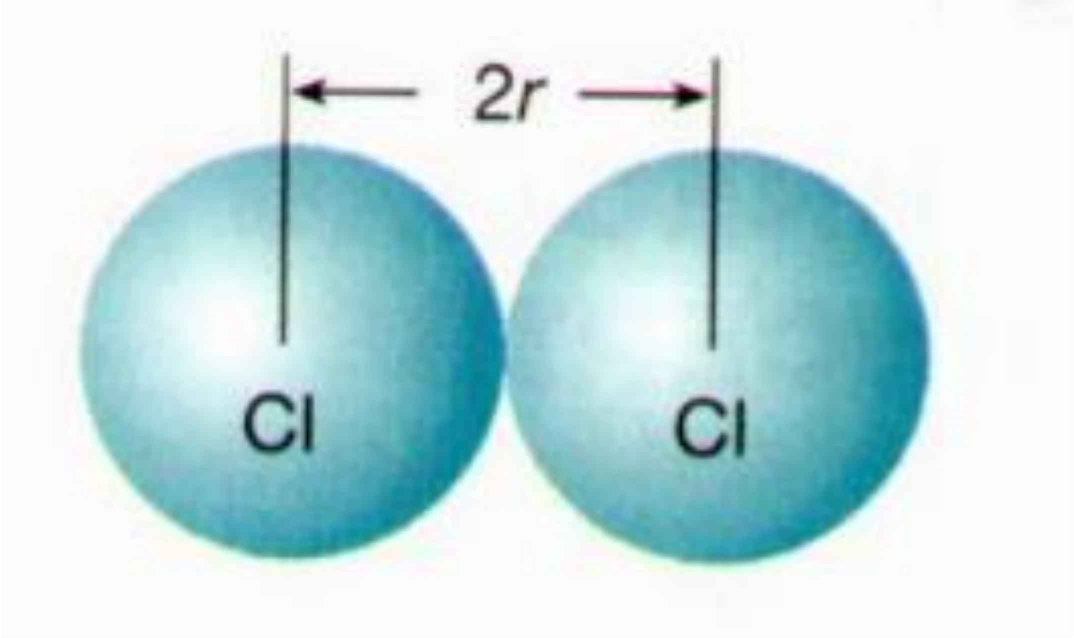
  3. Shielding effect – more levels of electrons repel and reduce pull on outer electrons.

What do they influence?

- Energy levels and Shielding have an effect on the *GROUP* (↓)
- Nuclear charge has an effect on a *PERIOD* (→)

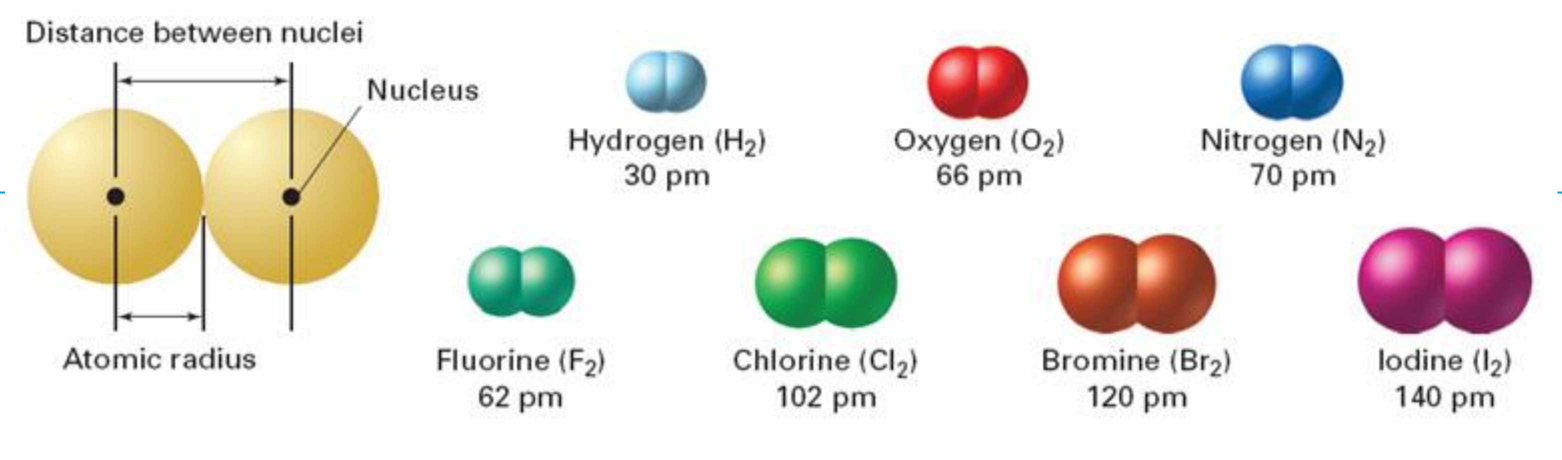
1. ATOMIC RADIUS/SIZE

- the radius of an atom (size)



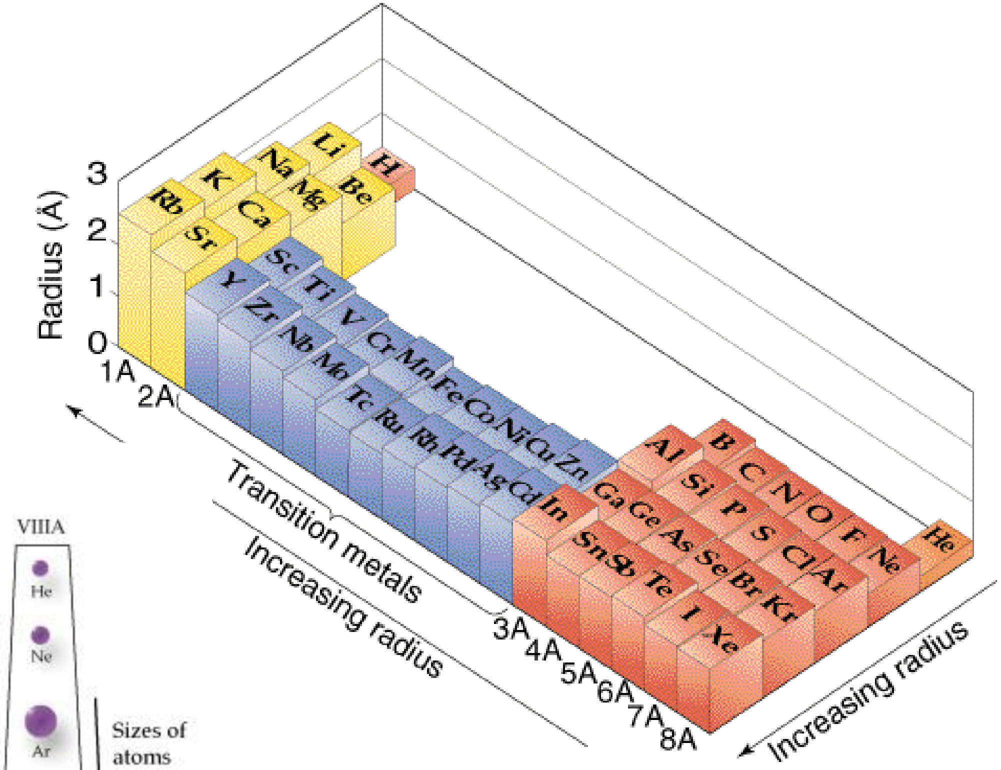
Trends in Atomic Size

- The atomic radius is one half of the distance between the nuclei of two atoms of the same element when the atoms are joined.
- In general, atomic size increases from top to bottom within a group and decreases from left to right across a period.

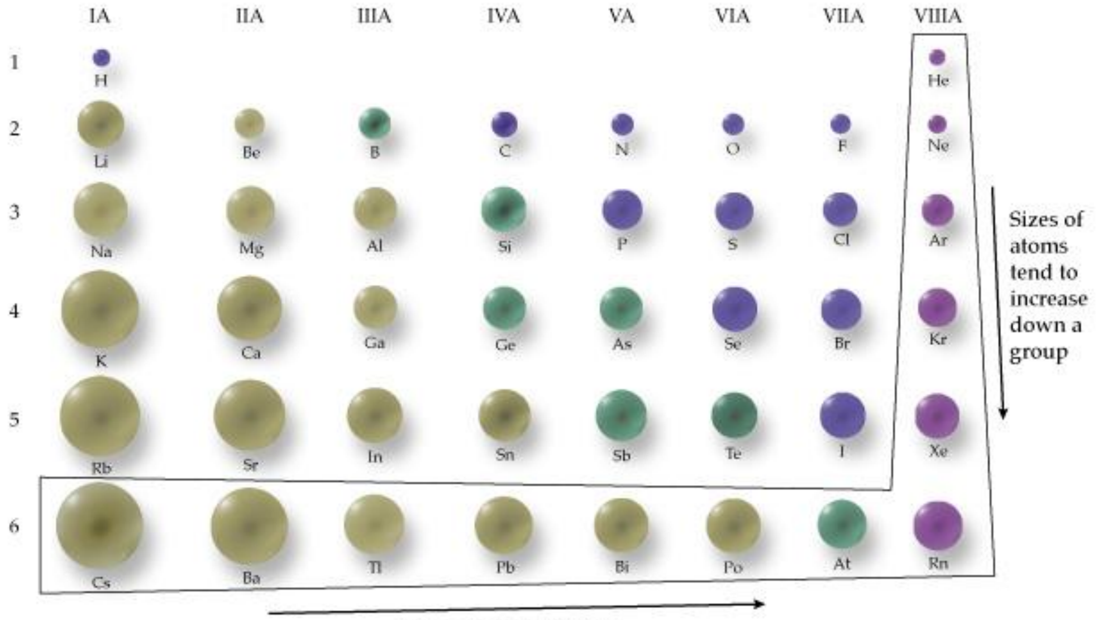


Trends in Atomic Size

- Largest atomic species are those found in the bottom left corner



Relative Atomic Sizes of the Representative Elements



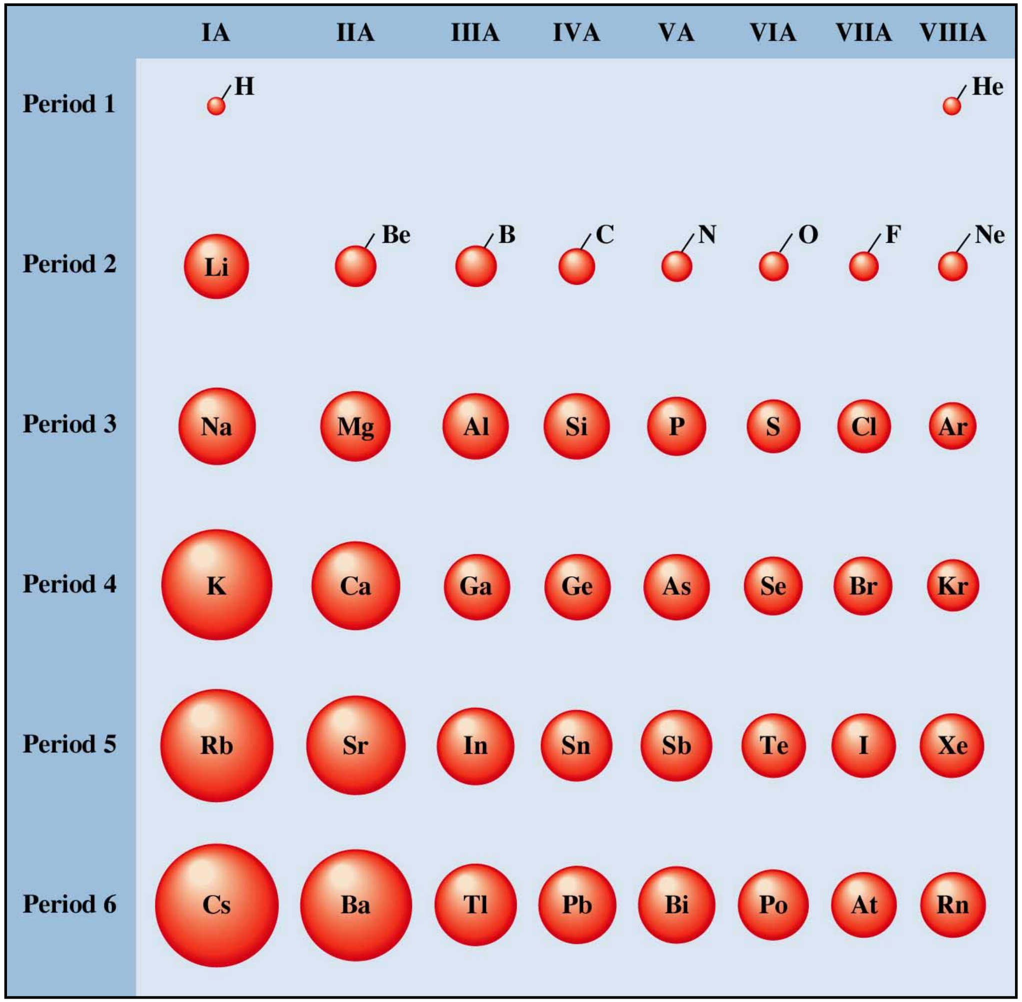
Sizes of atoms tend to increase down a group

Sizes of atoms tend to decrease across a period

Atomic Radius

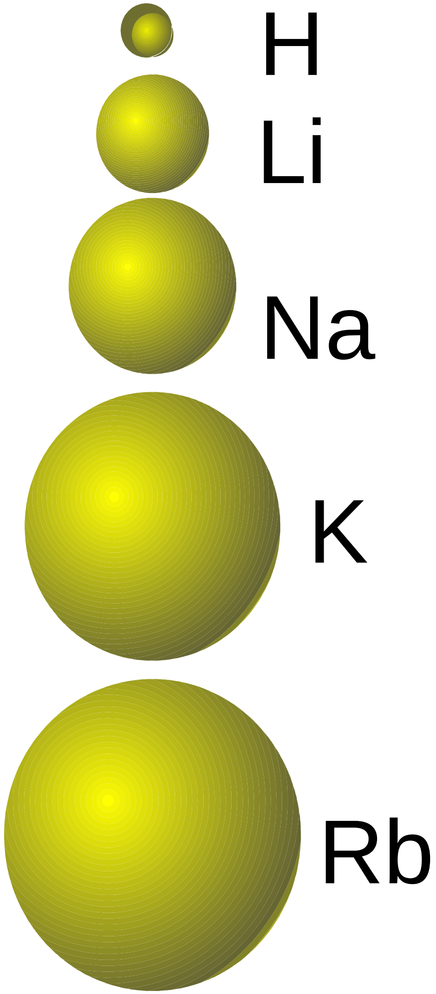
- Atomic radii actually decrease across a row in the periodic table, due to an increase in the nuclear charge.
- Within each group (vertical column), the atomic radius tends to increase with the period number. Not only is there an additional energy level but the shielding effect increases.

Atomic Radii for Main Group Elements



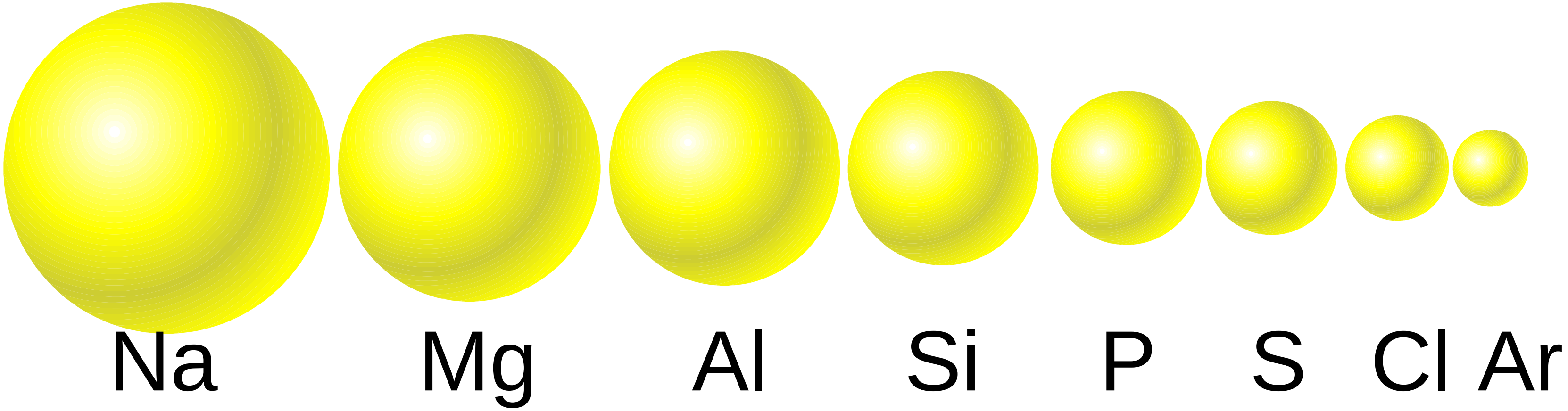
Atomic Size - Group trends

- As we increase the atomic number while going down a group…
- each atom has another energy level PLUS more shielding
- so the atoms get *bigger*.

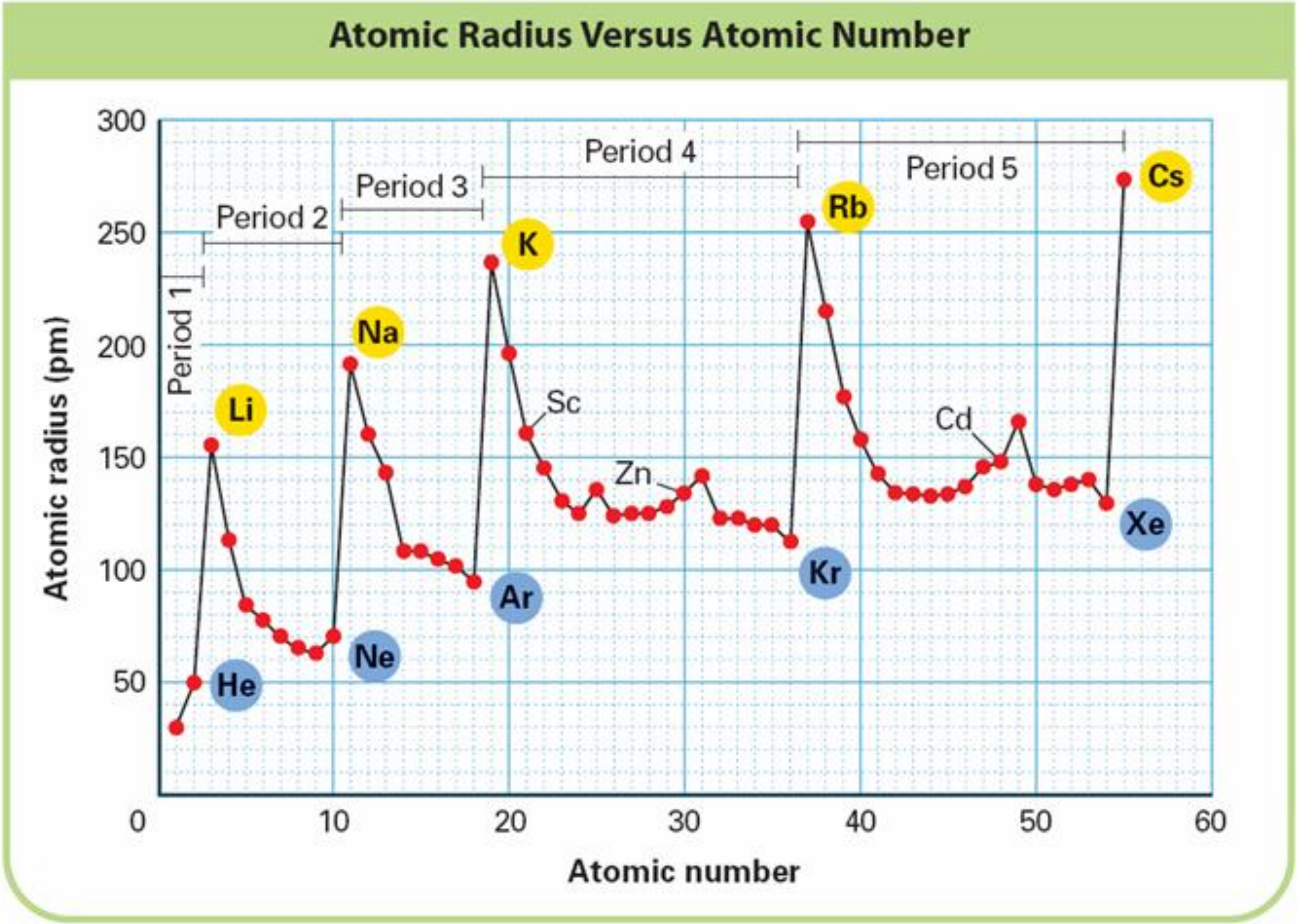


Atomic Size - Period Trends

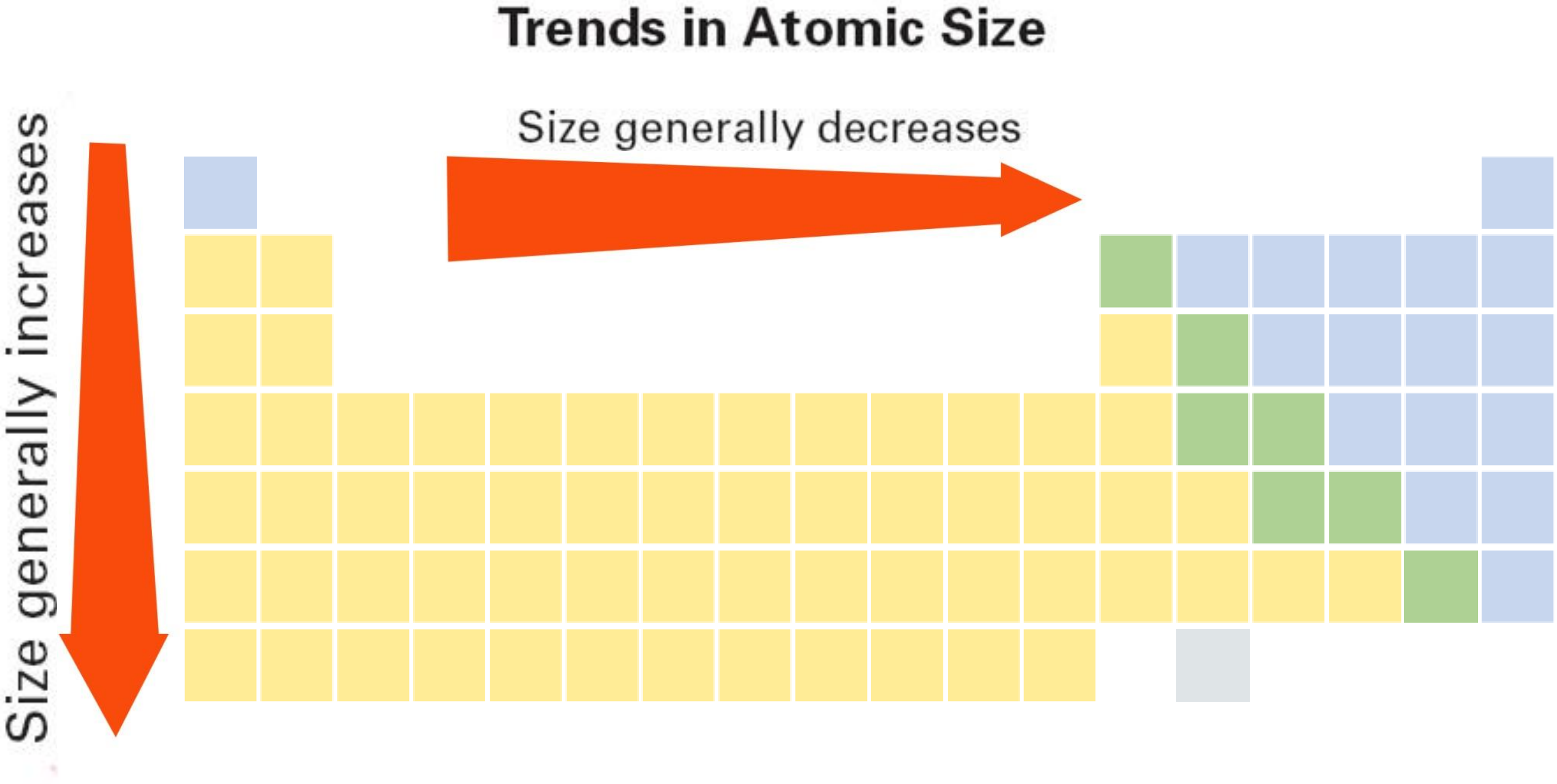
- Going from left to right across a period, the size gets smaller.
- Electrons are in the same energy level.
- But, there is more nuclear charge (more protons).
- Outermost electrons are pulled closer.



Trends in Atomic Size



Trends in Atomic Size



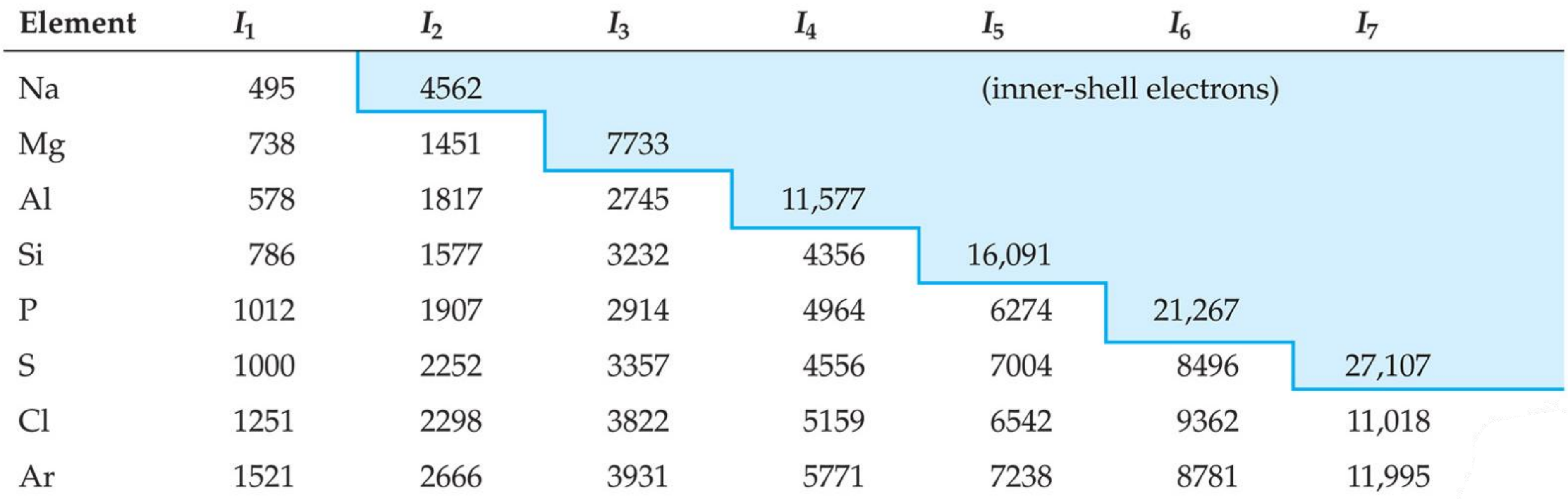
2. Trends in Ionization Energy

The energy required to remove an electron from the ground state of a gaseous atom or ion is called **ionization energy**.

- The energy required to remove the first electron from an atom is called the first ionization energy.
- The energy required to remove an electron from an ion with a 1+ charge is called the second ionization energy.
- i.e. Second ionization energy is that energy required to remove the second electron, etc.

Ionization Energy

- It requires more energy to remove each successive electron.
- When all valence electrons have been removed, the ionization energy takes a quantum leap.



Element	I_1	I_2	I_3	I_4	I_5	I_6	I_7
Na	495	4562			(inner-shell electrons)		
Mg	738	1451	7733				
Al	578	1817	2745	11,577			
Si	786	1577	3232	4356	16,091		
P	1012	1907	2914	4964	6274	21,267	
S	1000	2252	3357	4556	7004	8496	27,107
Cl	1251	2298	3822	5159	6542	9362	11,018
Ar	1521	2666	3931	5771	7238	8781	11,995

Symbol	First	Second	Third
H	1312		
He	2731	5247	
Li	520	7297	11810
Be	900	1757	14840
B	800	2430	3569
C	1086	2352	4619
N	1402	2857	4577
O	1314	3391	5301
F	1681	3375	6045
Ne	2080	3963	6276

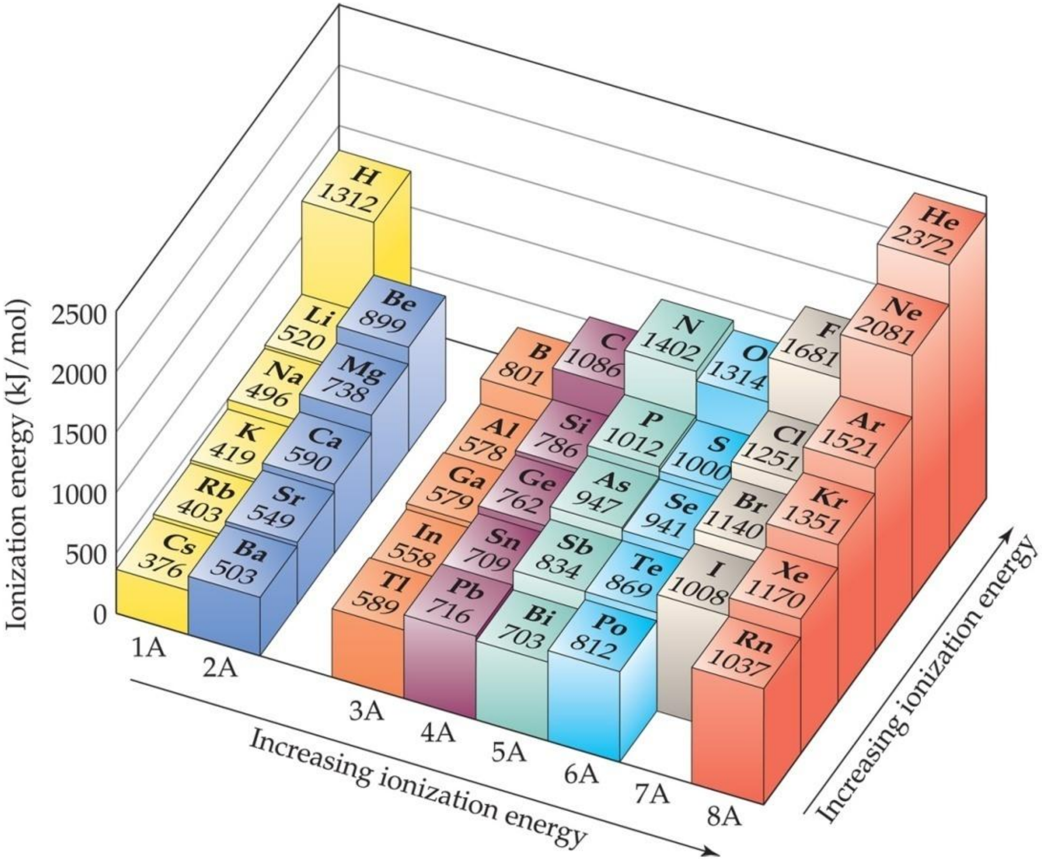
Why did these values increase **so much**?

Trends in Ionization Energy

Group and Periodic Trends in Ionization Energy

- First ionization energy tends to decrease from top to bottom within a group and increase from left to right across a period.

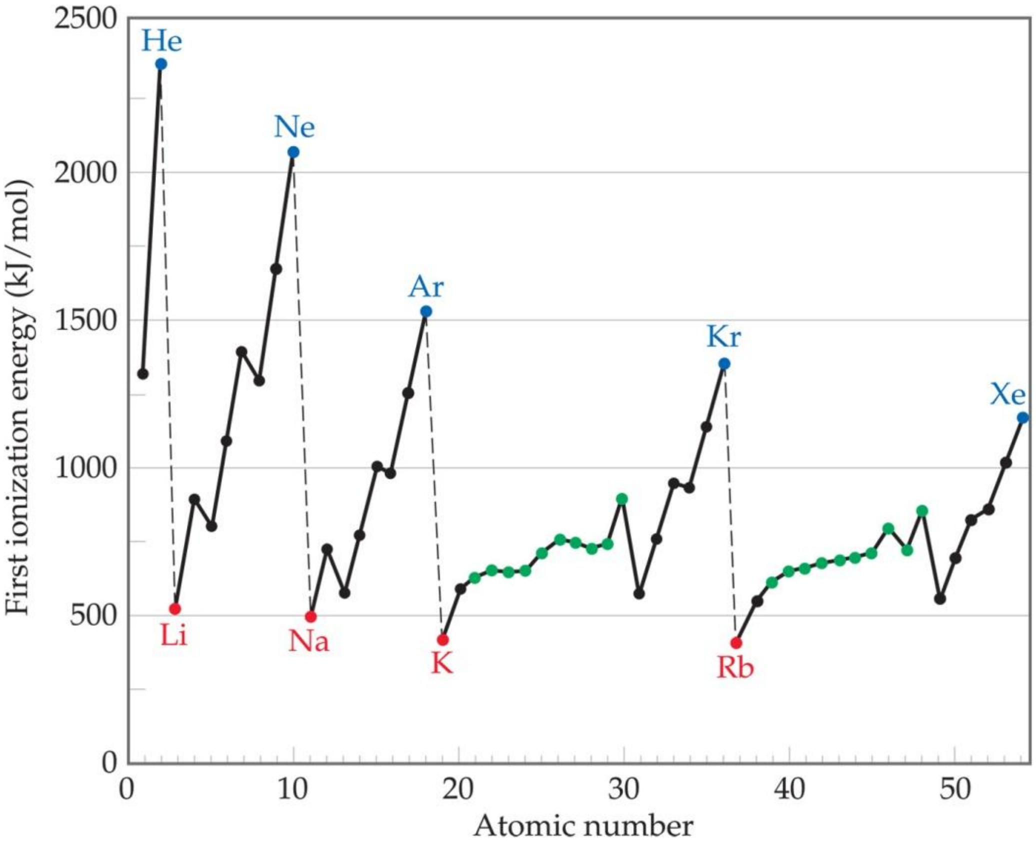
Trends in First Ionization Energies



- As one goes down a column, less energy is required to remove the first electron.
  - For atoms in the same group, the effective nuclear charge is essentially the same, but the valence electrons are farther from the nucleus; therefore more shielding.

Trends in First Ionization Energies

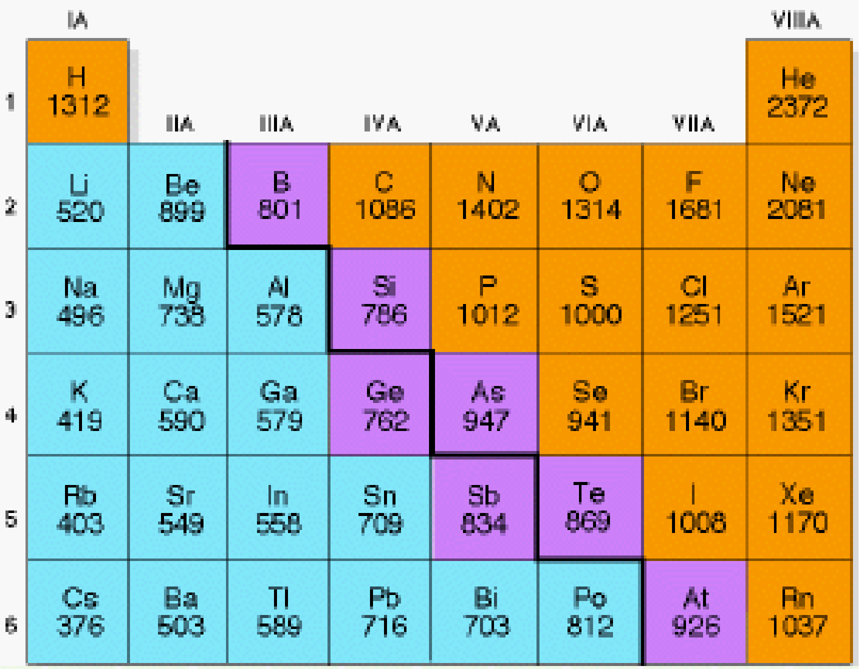
- Generally, as one goes across a row, it gets harder to remove an electron.
  - As you go from left to right, the nuclear charge increases, thus holding the electrons more tightly



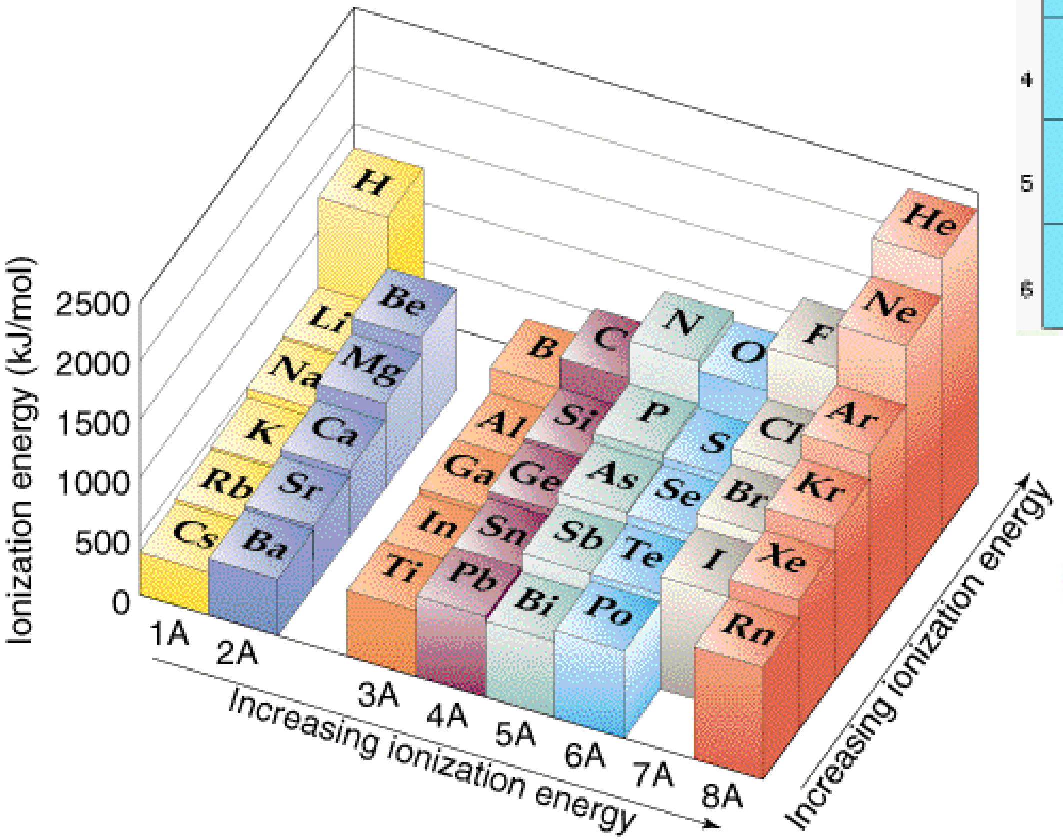
Trend in Ionization Energy

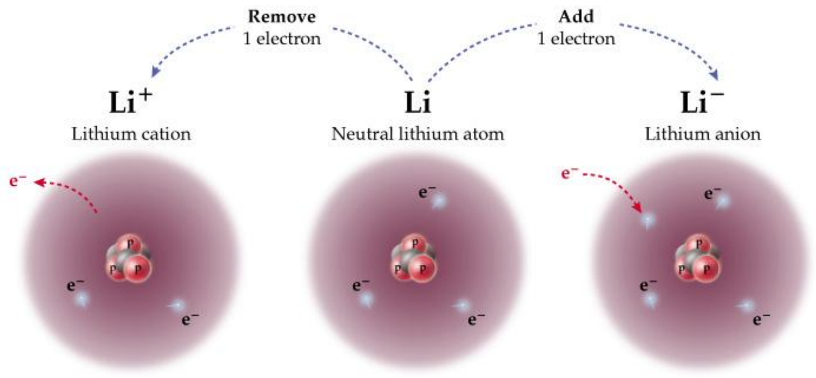
Ionization energy:

Largest toward top right corner of Periodic Table since these atoms hold onto their valence e- the tightest.

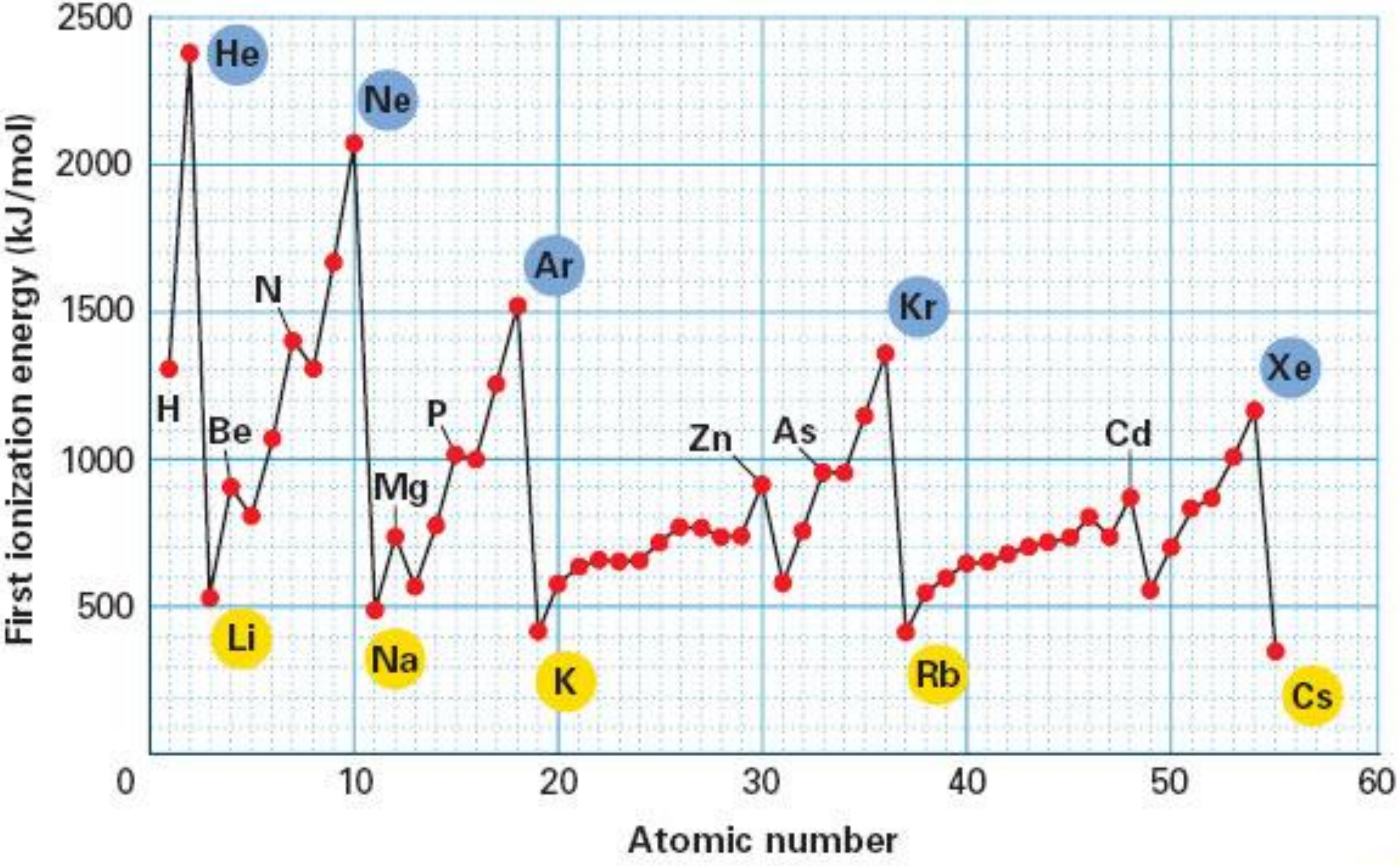


	IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
1	H 1312							He 2372
2	Li 520	Be 899	B 801	C 1086	N 1402	O 1314	F 1681	Ne 2081
3	Na 496	Mg 738	Al 578	Si 786	P 1012	S 1000	Cl 1251	Ar 1521
4	K 419	Ca 590	Ga 579	Ge 762	As 947	Se 941	Br 1140	Kr 1351
5	Rb 403	Sr 549	In 558	Sn 709	Sb 834	Te 869	I 1008	Xe 1170
6	Cs 376	Ba 503	Tl 589	Pb 716	Bi 703	Po 812	At 926	Rn 1037

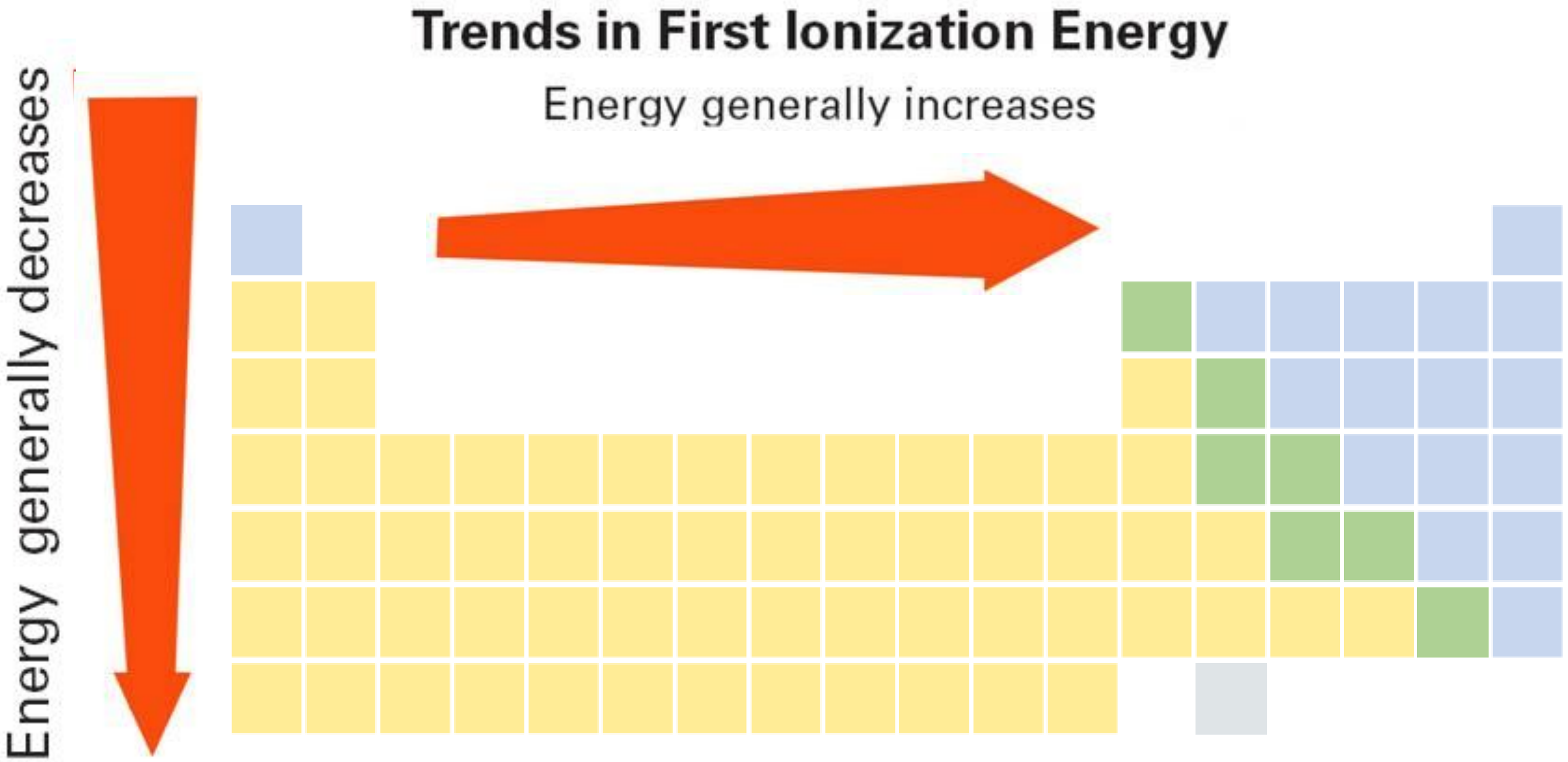




First Ionization Energy Versus Atomic Number



Trends in Ionization Energy



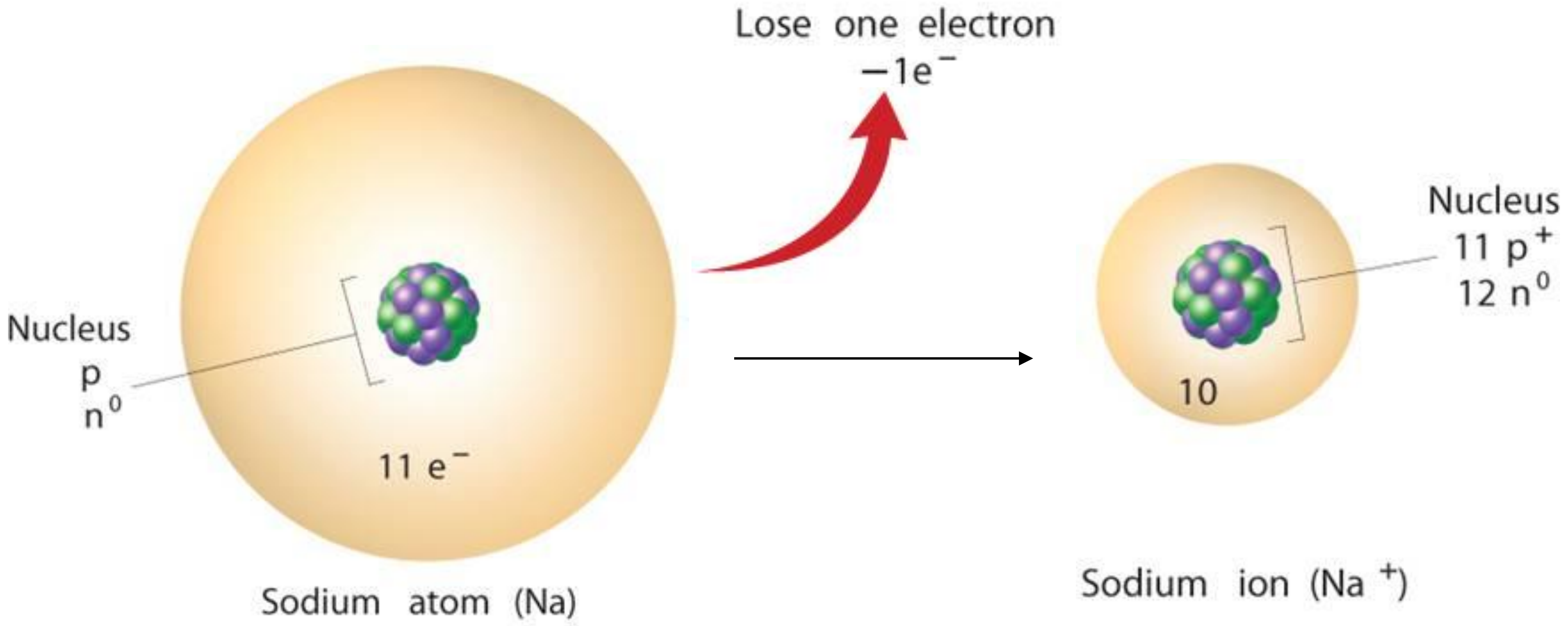
3. Trends in Ionic Size

- During reactions between metals and nonmetals, metal atoms tend to lose electrons, and nonmetal atoms tend to gain electrons. The transfer has a predictable effect on the size of the ions that form.

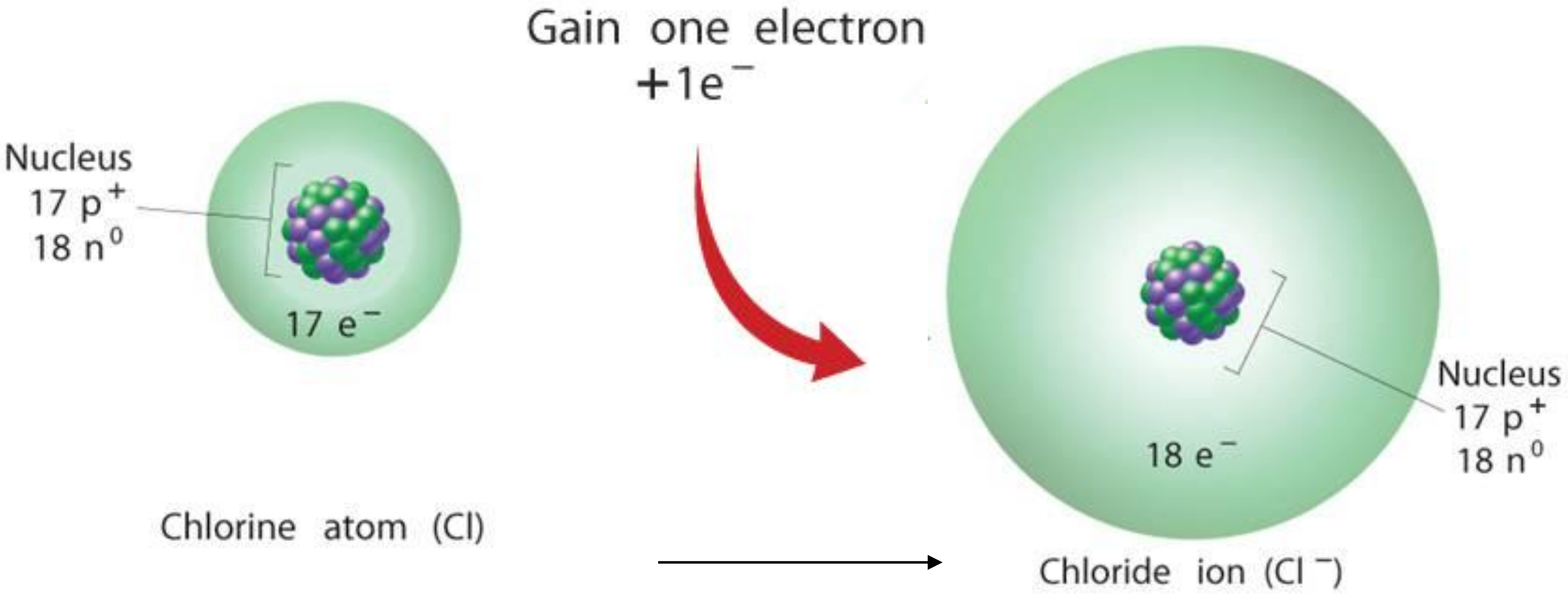
- **Cations** are always smaller than the atoms from which they form. **Anions** are always larger than the atoms from which they form.

Positive and negative ions form when electrons are transferred between atoms.

Forming a cation

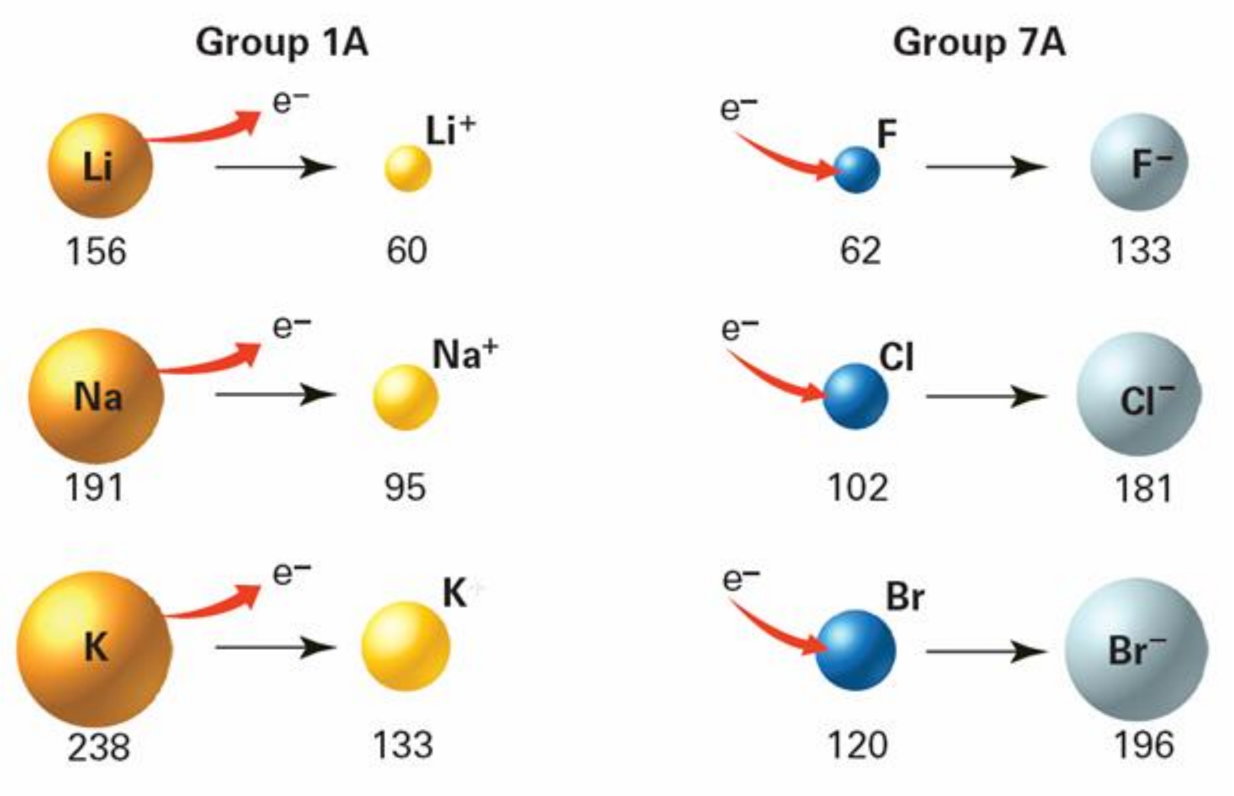


Forming an Anion



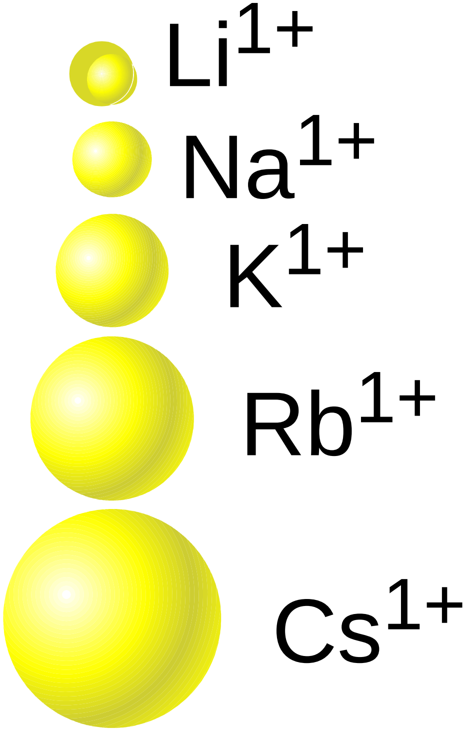
Trends in Ionic Size

- **Relative Sizes of Some Atoms and Ions**



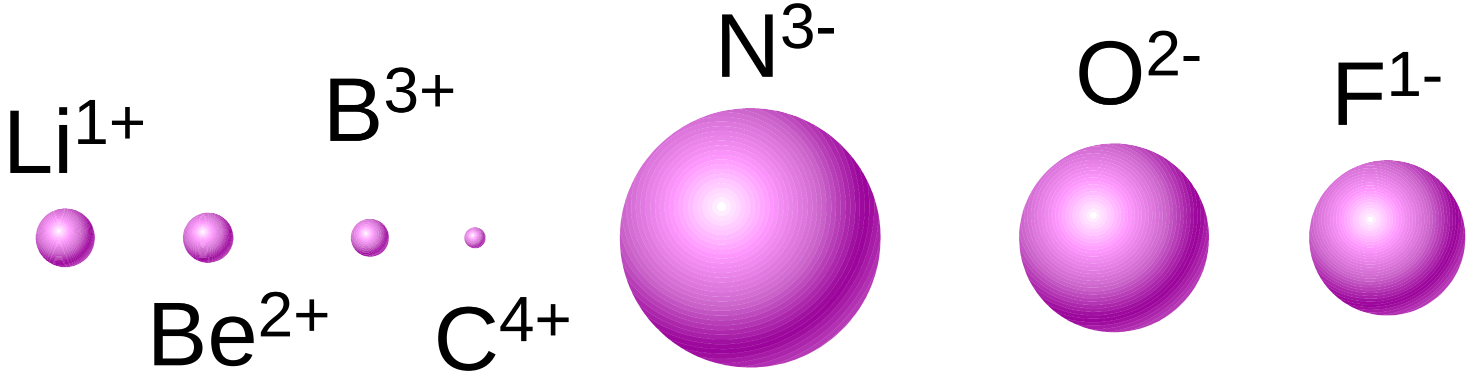
Ion Group trends

- Each step down a group is adding an energy level
- Ions therefore get <u>bigger</u> as you go down, because of the additional energy level.

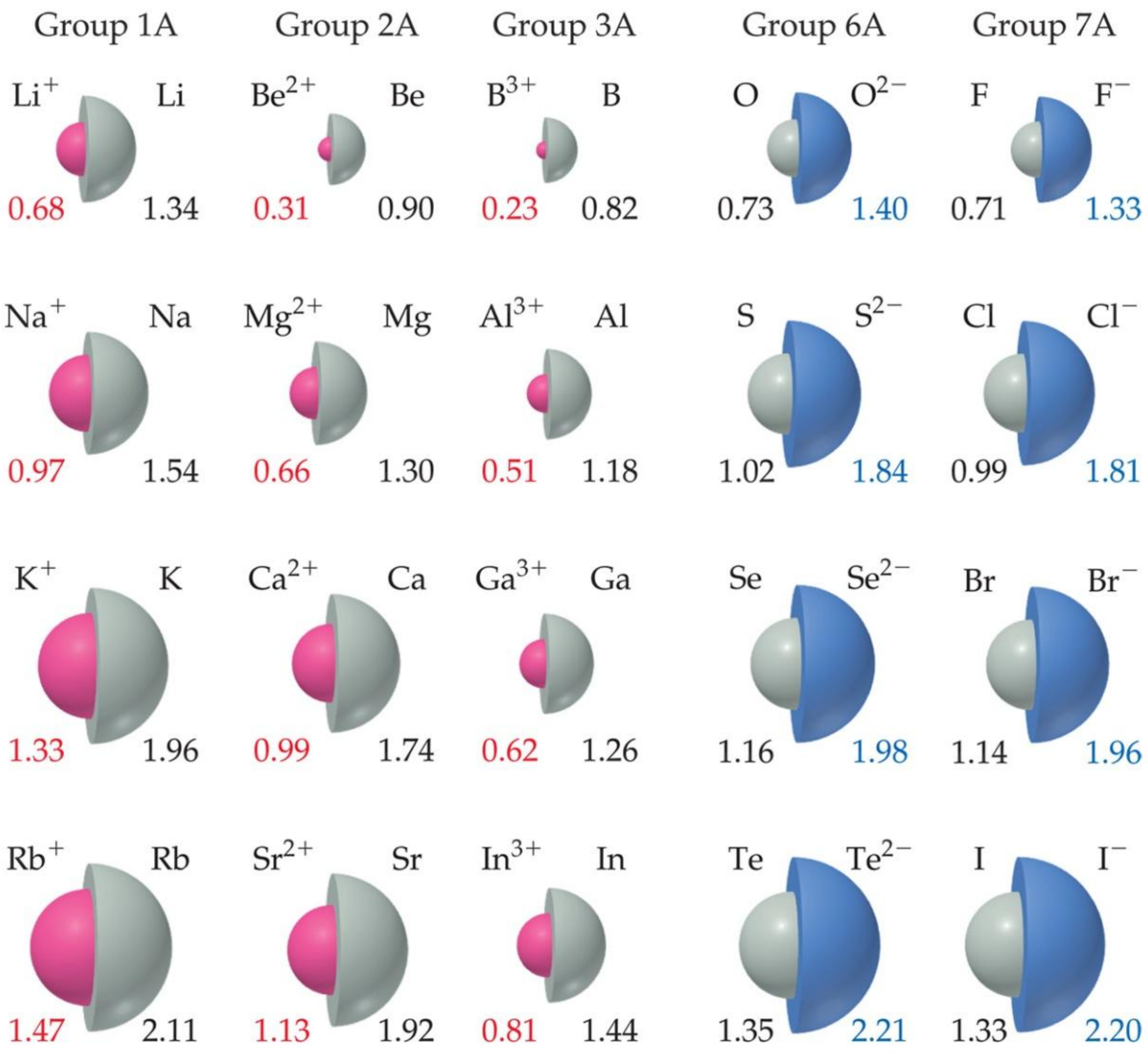


Ion Period Trends

- Across the period from left to right, the nuclear charge increases - so they get smaller.
- Notice the *energy level changes* between anions and cations.

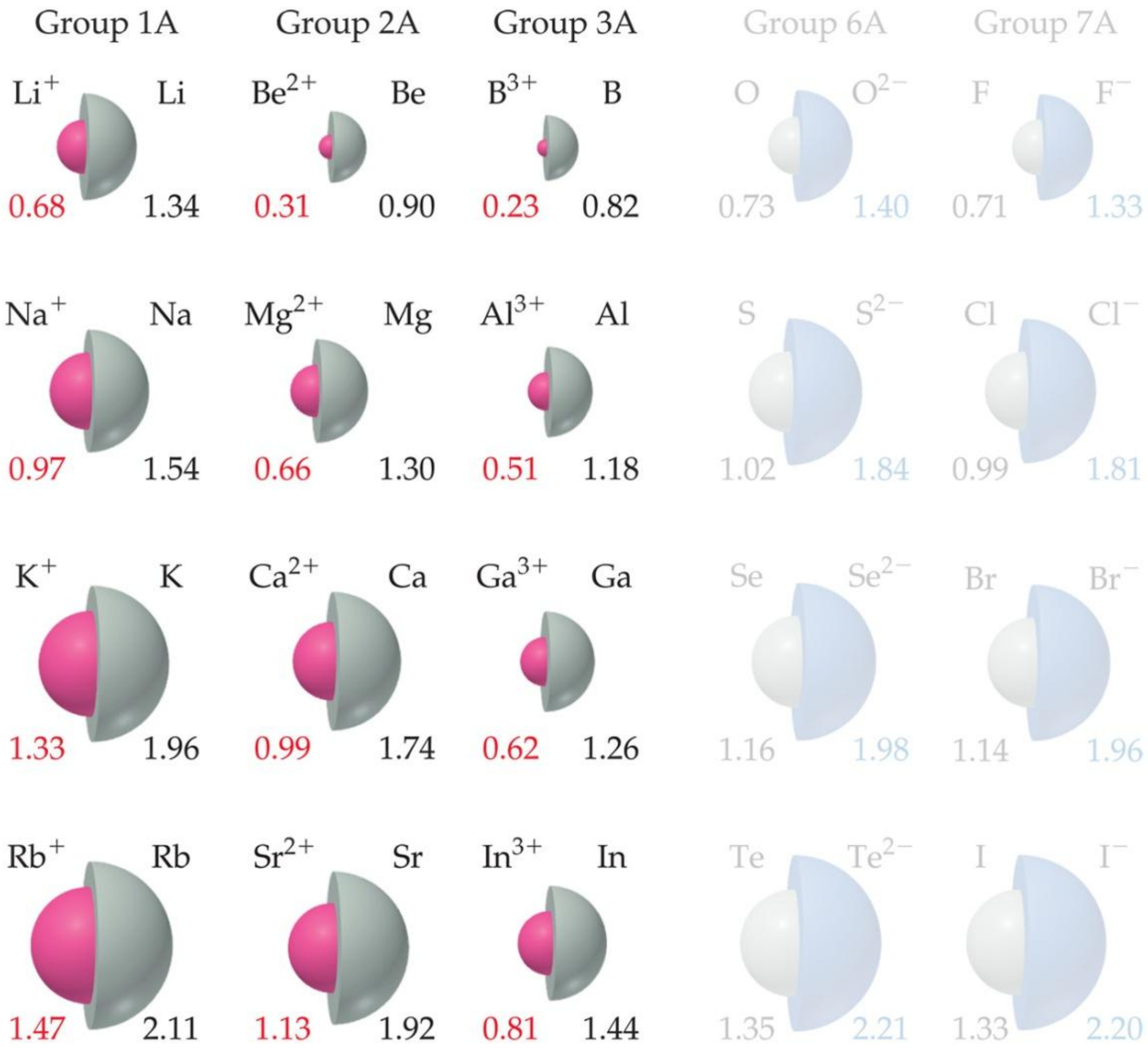


Sizes of Ions



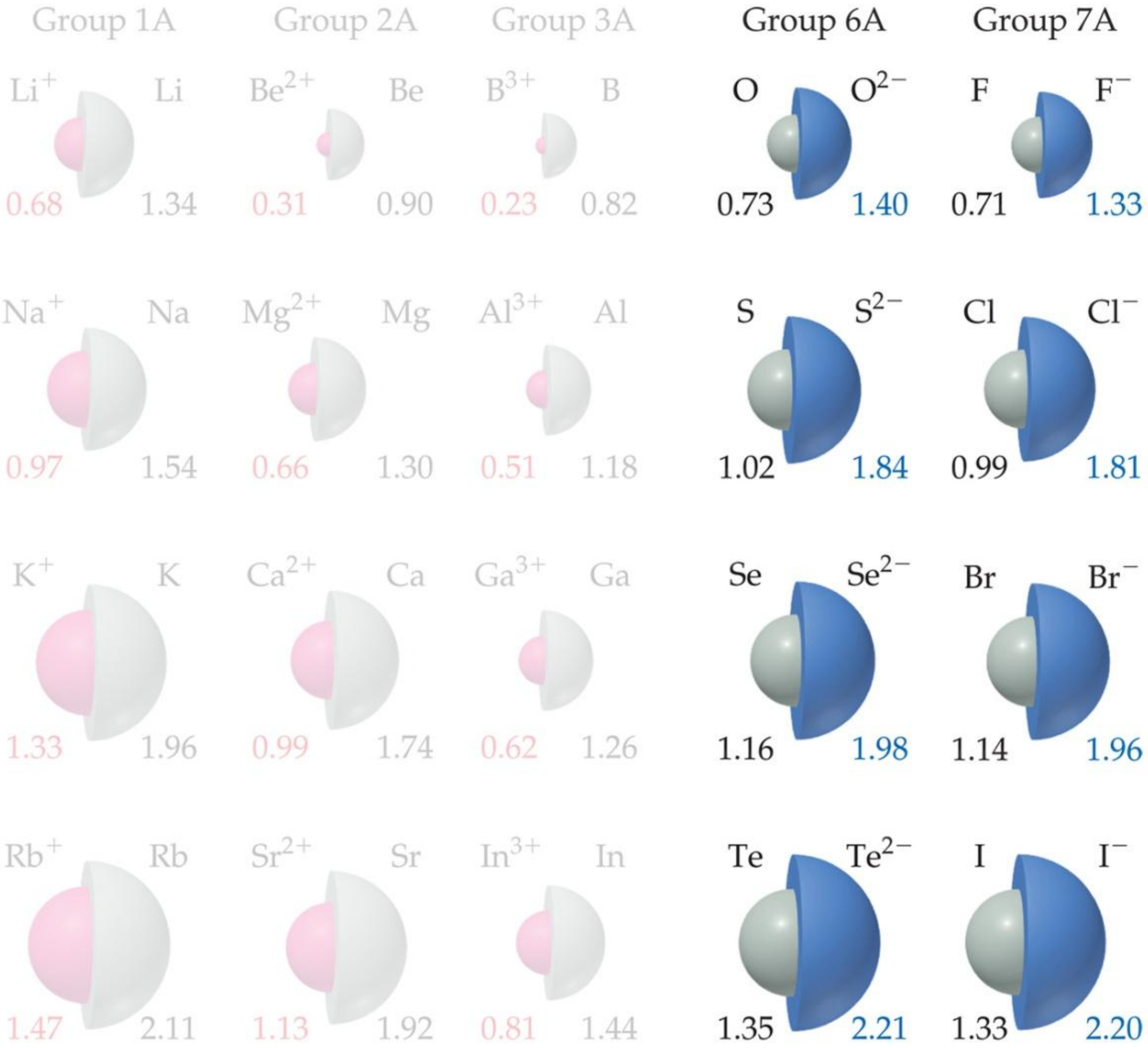
- Ionic size depends upon:
  - Nuclear charge.
  - Number of electrons.
  - Orbitals in which electrons reside.

Sizes of Ions



- Cations are smaller than their parent atoms.
  - The outermost electron is removed and repulsions are reduced.

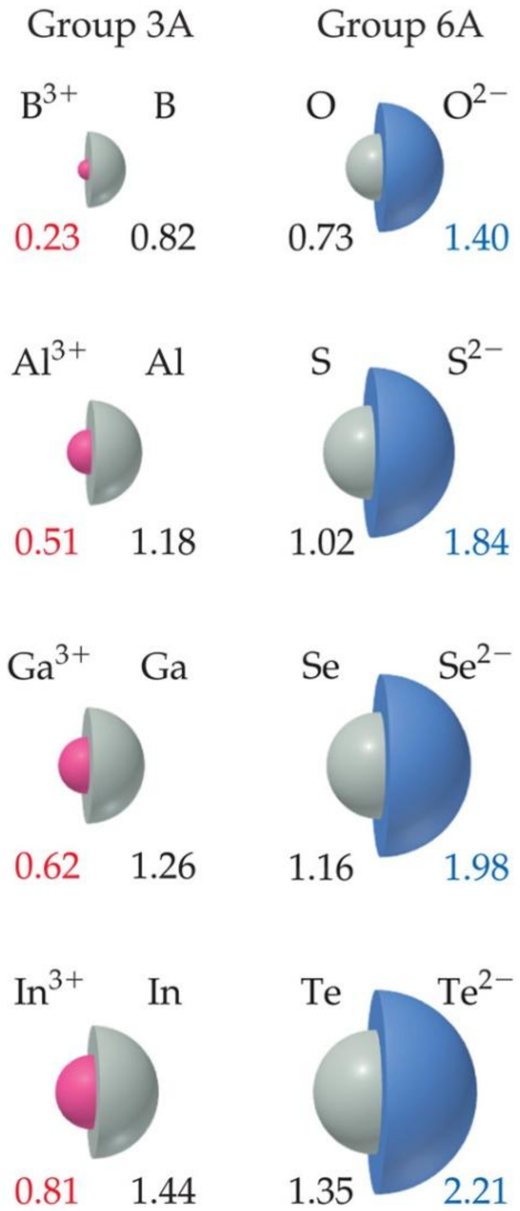
Sizes of Ions



- Anions are larger than their parent atoms.
  - Electrons are added and repulsions are increased.

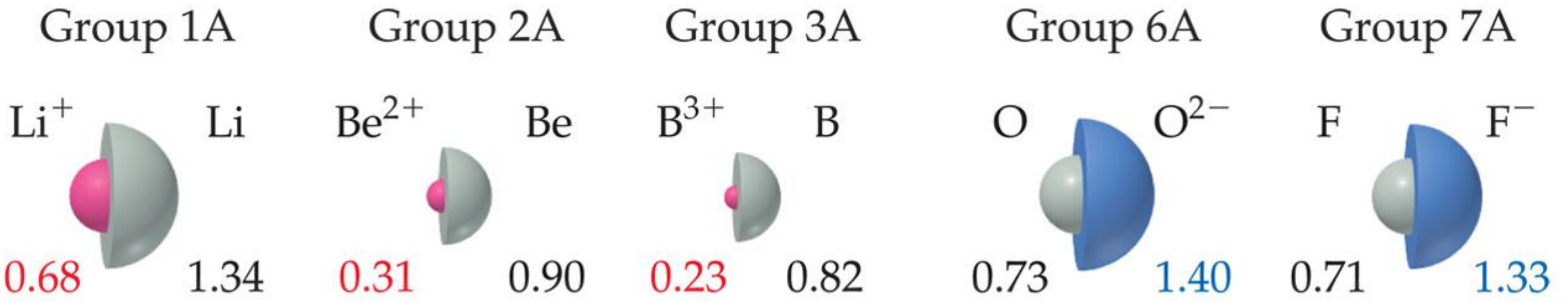
Sizes of Ions

- Ions increase in size as you go down a column.



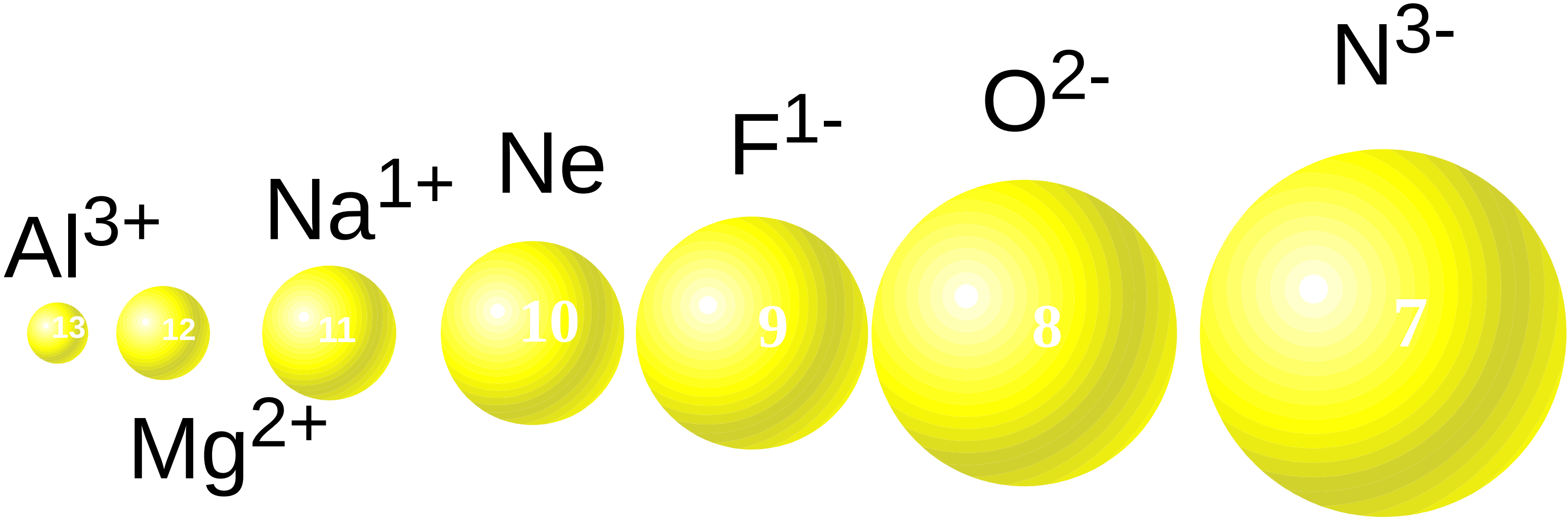
Sizes of Ions

- Isoelectronic means that ions have the same number of electrons. See the following examples.
- Ionic size decreases with an increasing nuclear charge.

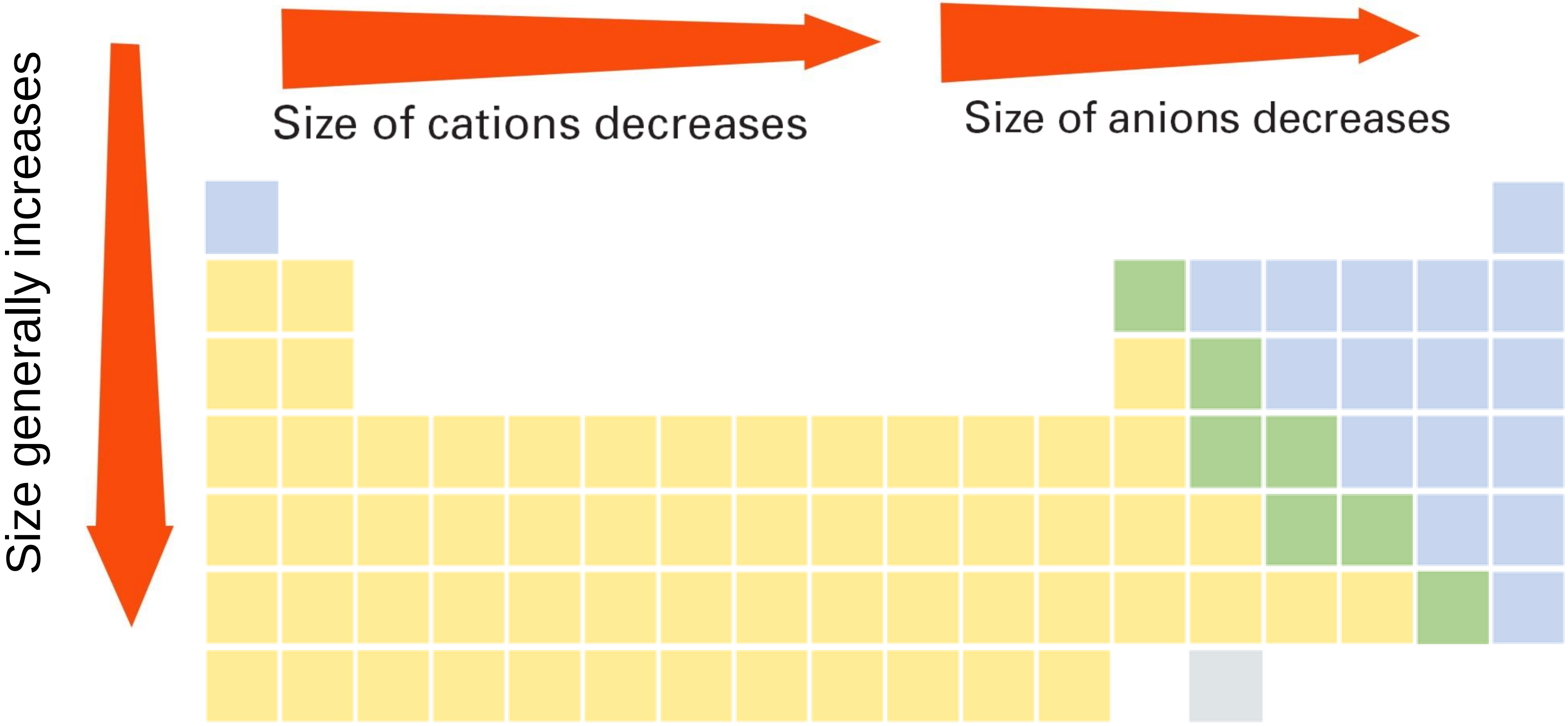


Size of Isoelectronic ions?

- Positive ions that have more protons would be *smaller* (more protons would pull the same # of electrons in closer)



Trends in Ionic Size



Size of cations decreases

Size of anions decreases

Size generally increases

4. Trends in Electronegativity

Electronegativity is the ability of an atom of an element to attract electrons when the atom is in a compound (i.e bonded).

- They share the electron, but how equally do they share it?
- An element with a big electronegativity means it pulls the electron towards itself strongly!
- In general, electronegativity values decrease from top to bottom within a group. The values tend to increase from left to right across a period.

Electronegativity Group Trend

- The further down a group, the farther the electron is away from the nucleus, plus the more electrons an atom has.
- Thus, more willing to share.
- Low electronegativity.

Electronegativity Period Trend

- Metals are at the left of the table.
- They let their electrons go easily
- Thus, low electronegativity
- At the right side are the nonmetals.
- They want more electrons.
- Try to take them away from others
- High electronegativity.

Trends in Electronegativity

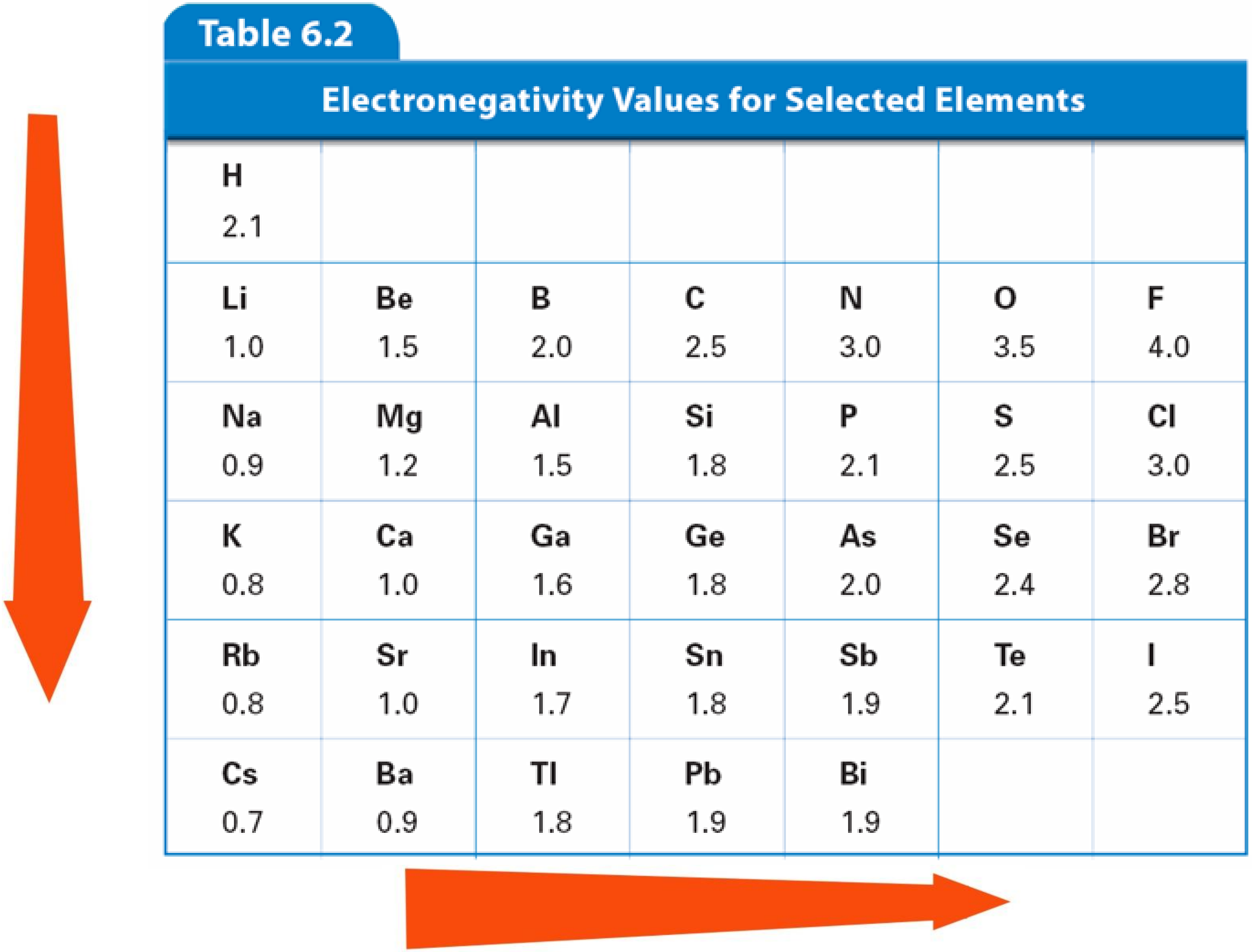


Table 6.2

Electronegativity Values for Selected Elements

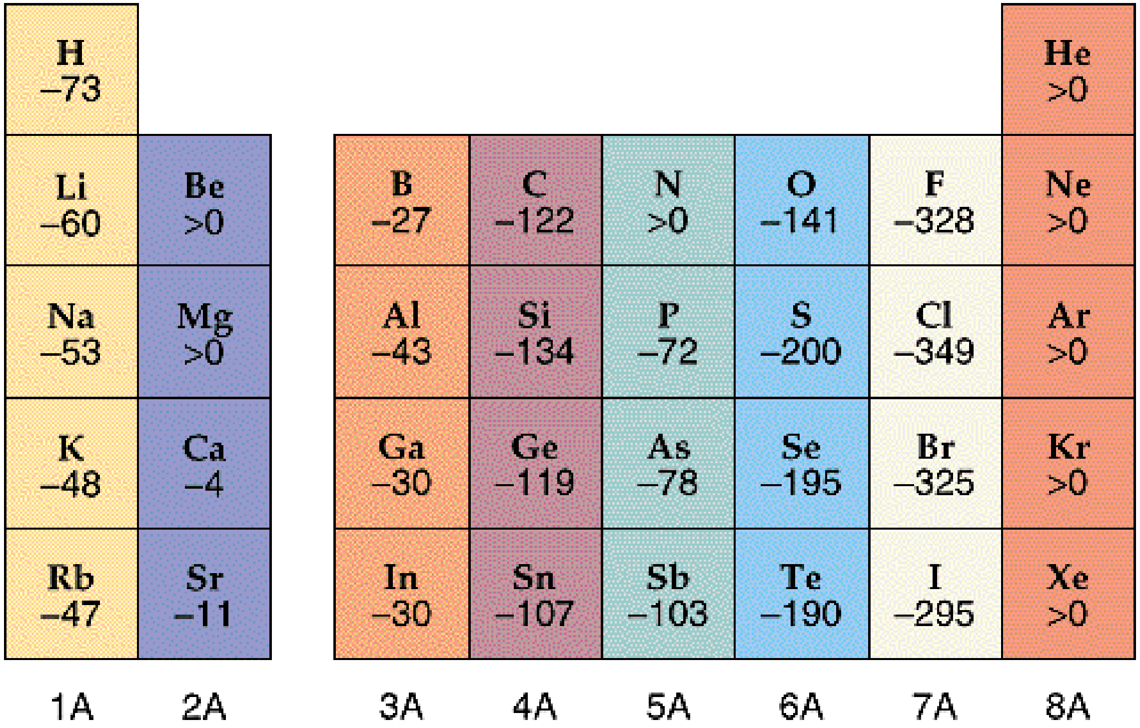
H 2.1						
Li 1.0	**Be** 1.5	**B** 2.0	**C** 2.5	**N** 3.0	**O** 3.5	**F** 4.0
Na 0.9	**Mg** 1.2	**Al** 1.5	**Si** 1.8	**P** 2.1	**S** 2.5	**Cl** 3.0
K 0.8	**Ca** 1.0	**Ga** 1.6	**Ge** 1.8	**As** 2.0	**Se** 2.4	**Br** 2.8
Rb 0.8	**Sr** 1.0	**In** 1.7	**Sn** 1.8	**Sb** 1.9	**Te** 2.1	**I** 2.5
Cs 0.7	**Ba** 0.9	**Tl** 1.8	**Pb** 1.9	**Bi** 1.9		

5. Trend in Electron Affinity

Electron Affinity:

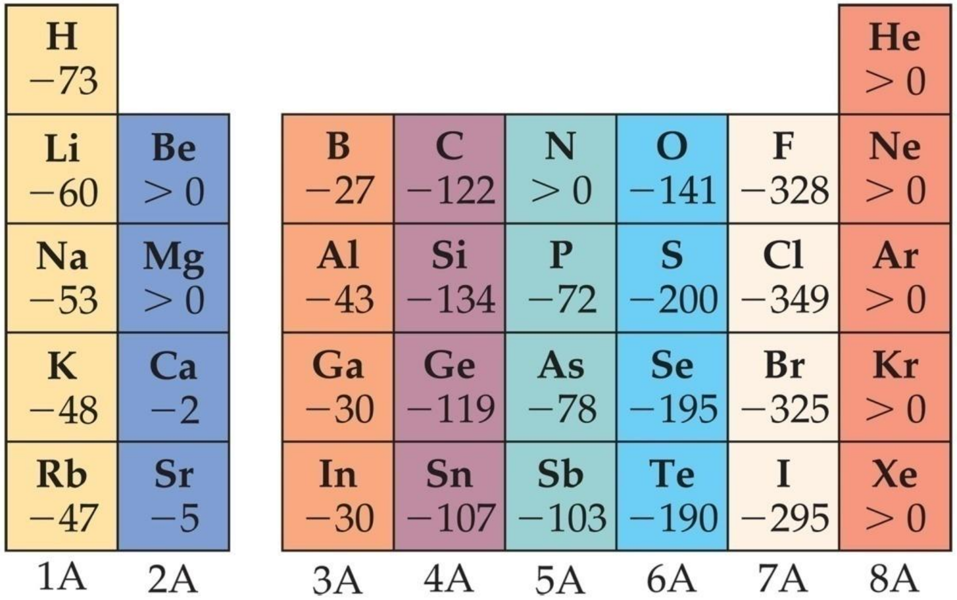
The energy released when an electron is added to a gaseous atom. Most favorable toward top right corner of Periodic Table since these atoms have a great affinity for e-.

$$Cl + e^- \longrightarrow Cl^-$$



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 –4	Ga –30	Ge –119	As –78	Se –195	Br –325	Kr >0
Rb –47	Sr –11	In –30	Sn –107	Sb –103	Te –190	I –295	Xe >0

Trends in Electron Affinity

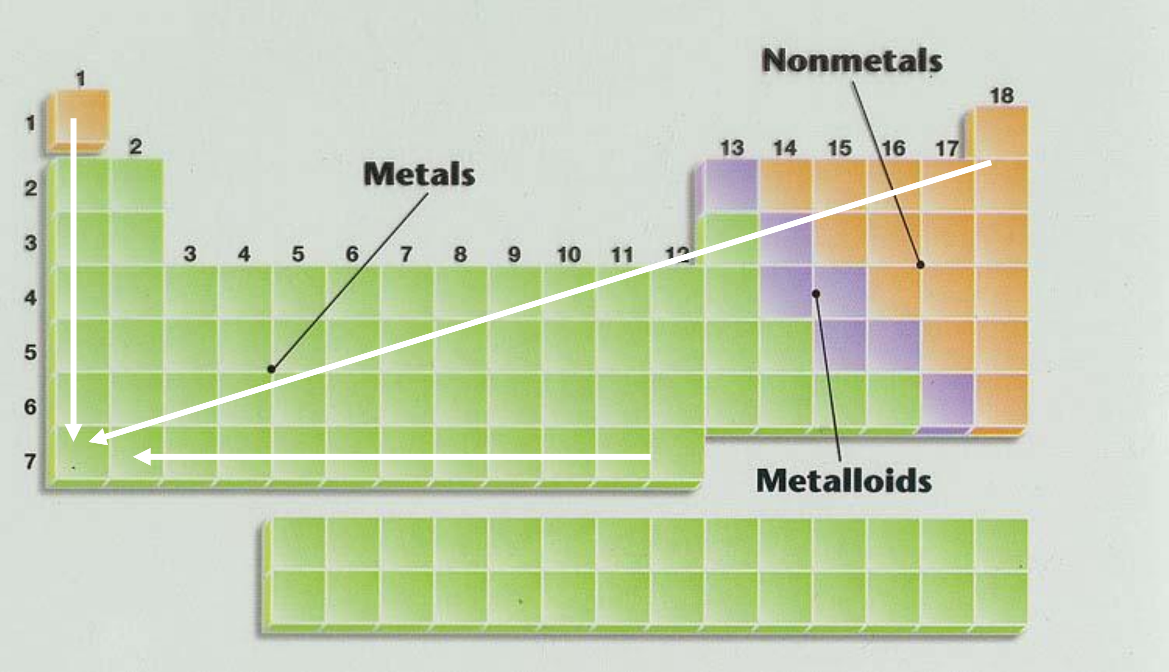


H −73							**He** > 0
Li −60	**Be** > 0	**B** −27	**C** −122	**N** > 0	**O** −141	**F** −328	**Ne** > 0
Na −53	**Mg** > 0	**Al** −43	**Si** −134	**P** −72	**S** −200	**Cl** −349	**Ar** > 0
K −48	**Ca** −2	**Ga** −30	**Ge** −119	**As** −78	**Se** −195	**Br** −325	**Kr** > 0
Rb −47	**Sr** −5	**In** −30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

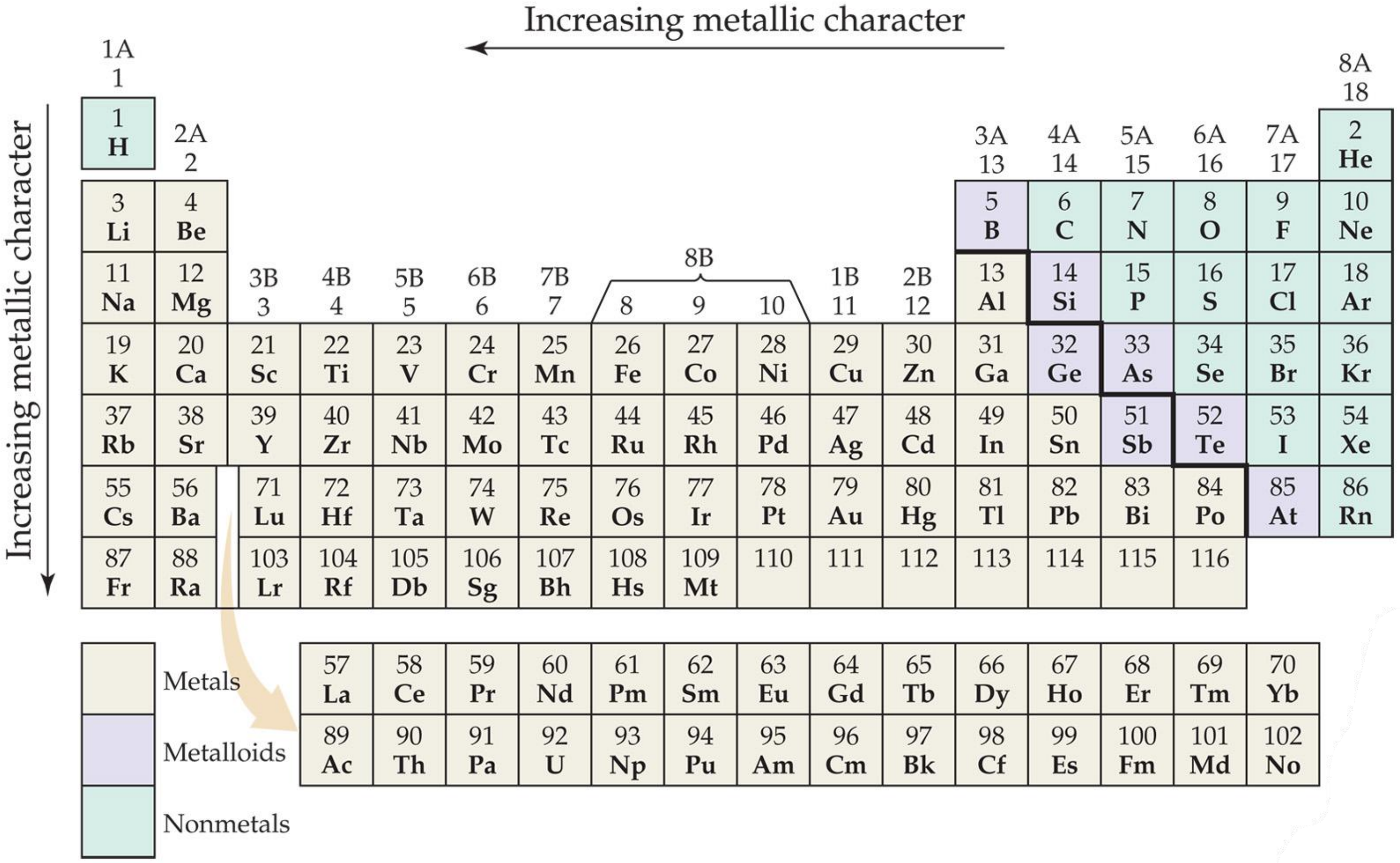
In general, electron affinity increases and becomes more exothermic as you go from left to right across a row. It also increases and becomes more exothermic as you go up the groups (from bottom to top).

6. Metallic Character

- This is simply a relative measure of how easily atoms lose or give up electrons.
- The most metallic elements (the ones that give up electrons the easiest) are found in the bottom left corner of the periodic table.



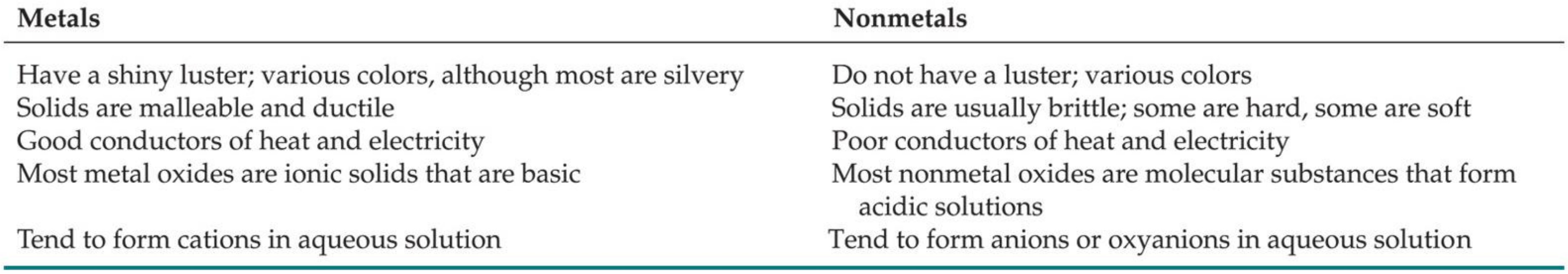
Properties of Metal, Nonmetals, and Metalloids



1A 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	9	10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
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	113	114	115	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

Review of Metals versus Nonmetals

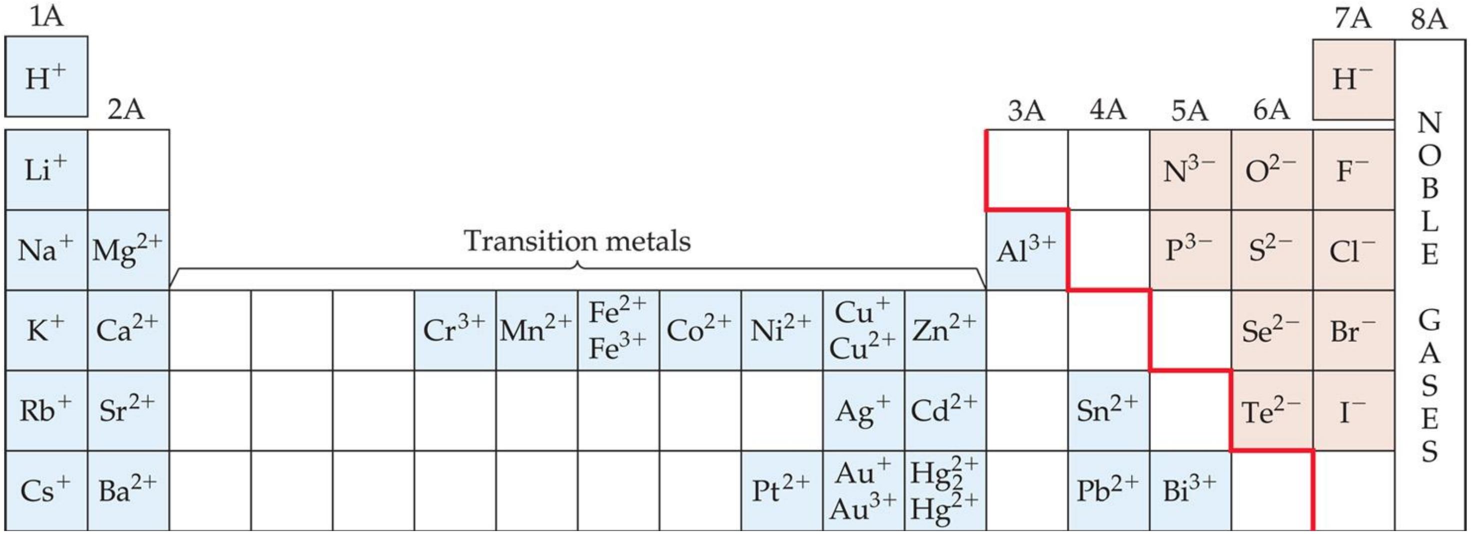


Metals	Nonmetals
Have a shiny luster; various colors, although most are silvery	Do not have a luster; various colors
Solids are malleable and ductile	Solids are usually brittle; some are hard, some are soft
Good conductors of heat and electricity	Poor conductors of heat and electricity
Most metal oxides are ionic solids that are basic	Most nonmetal oxides are molecular substances that form acidic solutions
Tend to form cations in aqueous solution	Tend to form anions or oxyanions in aqueous solution

Differences between metals and nonmetals tend to revolve around these properties.

Metals versus Nonmetals

- Metals tend to form cations.
- Nonmetals tend to form anions.



Summary of Trends

- What is the underlying cause of periodic trends?
  - **The trends that exist among these properties can be explained by variations in atomic structure, nuclear charge and shielding effect...**

In your notebook, you should have a periodic table with all of the trends described: atomic size, ionization energy, ionic size, eletronegativity, electron affinity, metallic properties. See the following three examples:

Summary of Periodic Trends

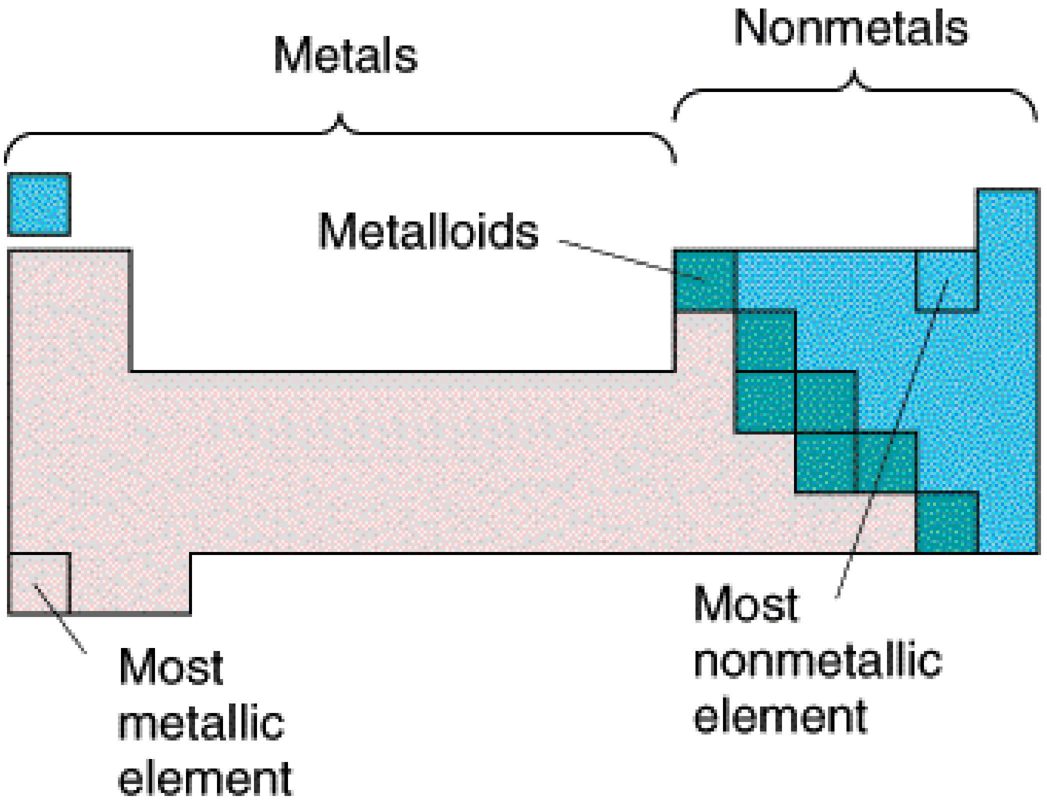
Increasing electron affinity

Increasing ionization energy

Decreasing atomic radius

Increasing nonmetallic character and electronegativity

Decreasing metallic character



Decreasing ionization energy

Increasing atomic radius

Decreasing electronegativity

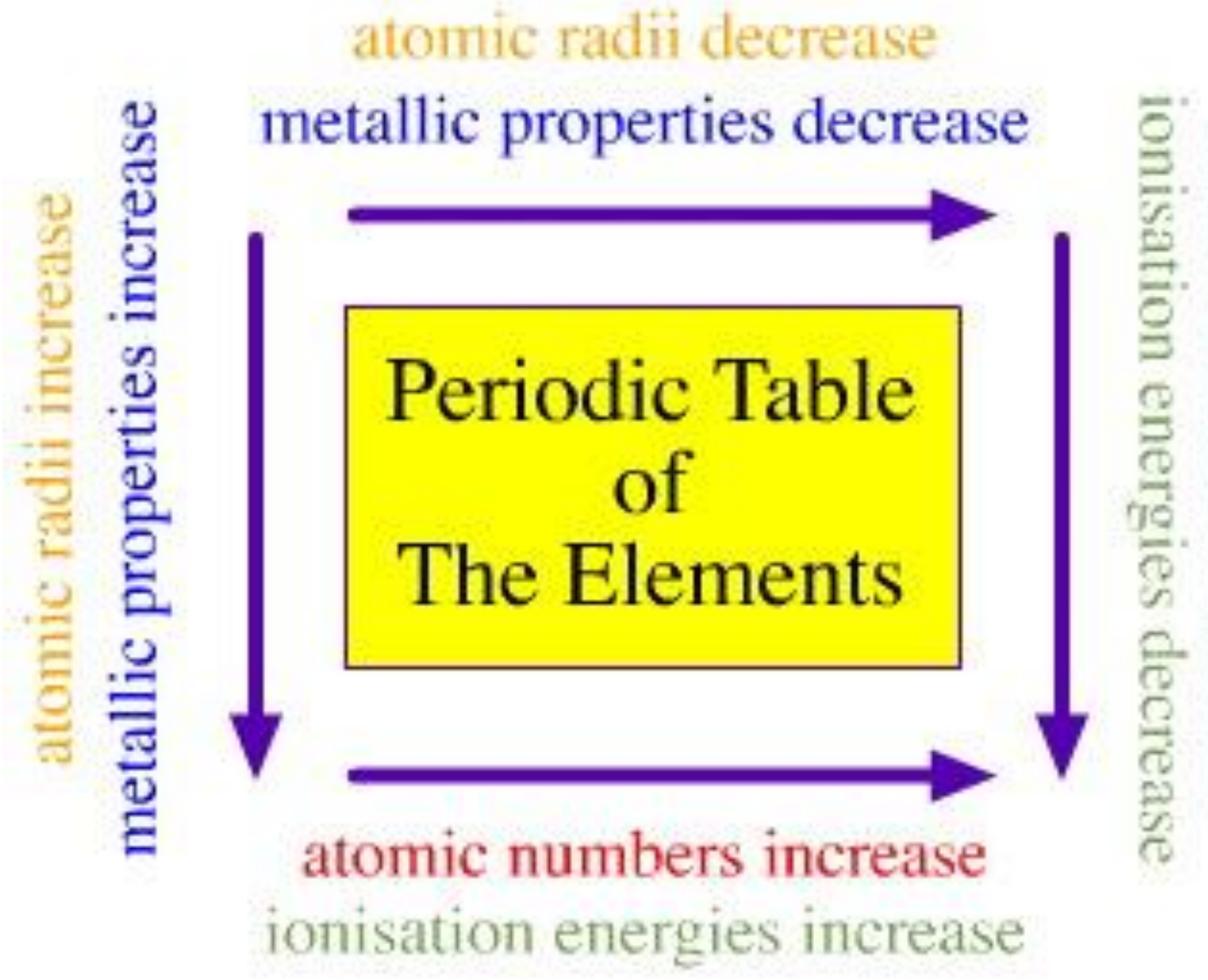
Increasing metallic character

Decreasing electron affinity

Summary of Periodic Trends, v.2

Electronegativity and Electron affinity increases

Electronegativity & Electron affinity decreases



Simplified Version

Metallic character

Ionic Size