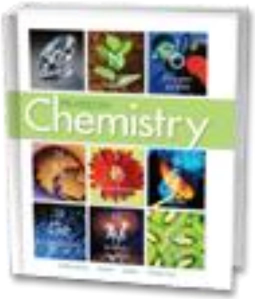


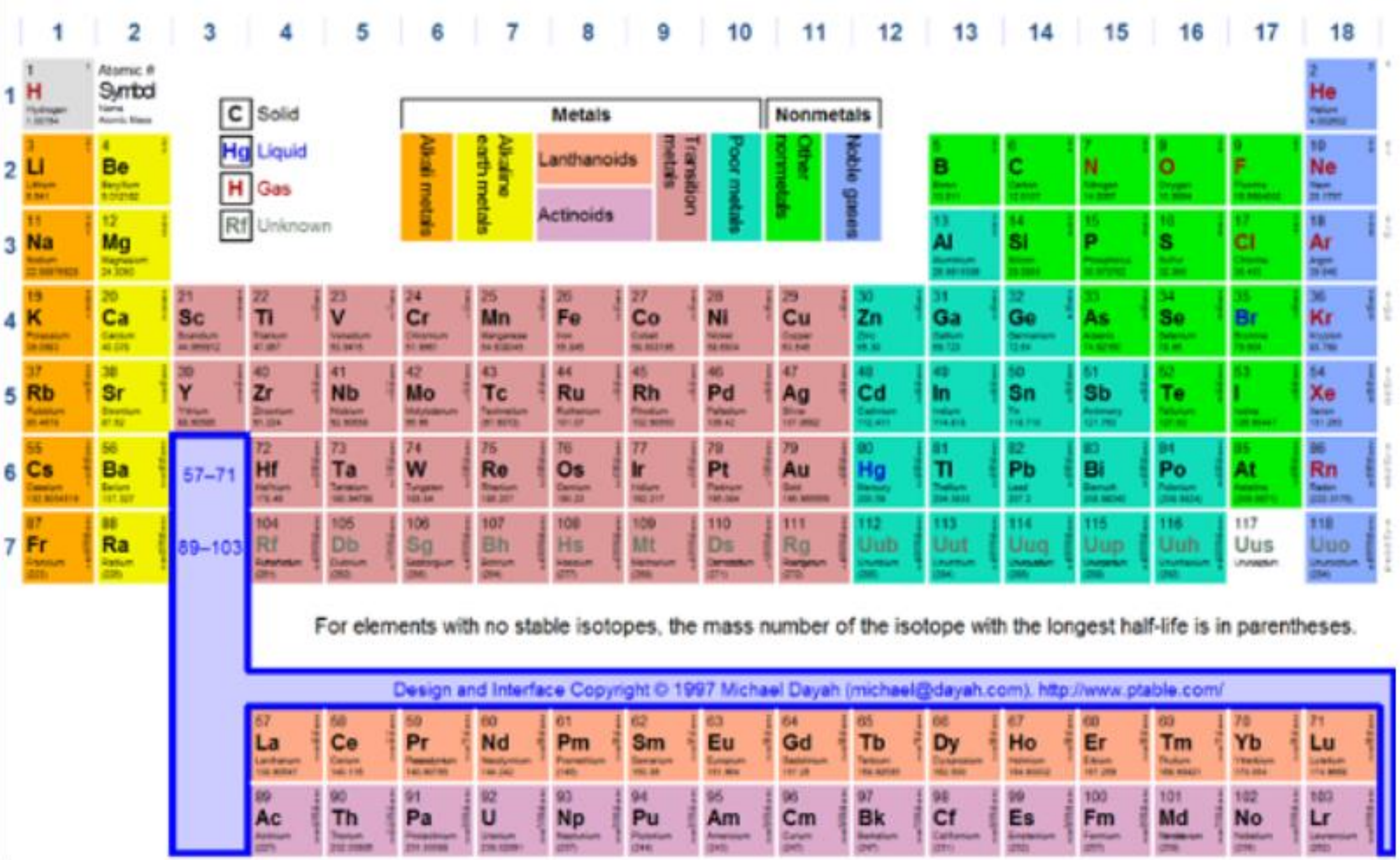
Chapter 6
The Periodic Table

Organizing the Elements

Classifying the Elements

Periodic Trends

Periodic Table of Elements



Topics:

1. The Periodic Table

Objectives:

1. Explain the history of the Periodic Table (Dobereiner, Newlands, Mendeleev, Moseley).
2. Describe the arrangement of the periodic table (periods, groups, periodic law, classes of elements).
3. Classify elements based on electron configuration for Valence (outer electrons that bond).
4. Explain periodic trends (electronegativity, atomic & ionic size, ionization energy)

EARSON

WARM-UP

Copy the chart below in your notebook:

The top row is the order of the EM spectra

radio	microwave	infrared	Visible ROY	Visible GBIV	ultraviolet	x-rays	gamma

WARM-UP

Observe the items in all 24 squares below in terms of similar characteristics.

Fill in the columns and rows (for the chart you copied) based on a recognizable & sensible pattern of the items.

Meat radio	Seafood microwave	Soup infrared	Dairy Visible ROY	Breads Visible GBIV	Vegetables ultraviolet	Pasta x-rays	Fruit gamma
Pork 0.5 lb radio	Salmon steak microwave	Beans 5 pods ultraviolet	Milk 1 gallon visible ROY	Grapes 1 twig gamma	Beef 0.25 lb radio	Tomato Soup 8 oz infrared	Rye 1 loaf visible GBIV
Stew 32 oz infrared	Spaghetti 1 pot x-rays	Bananas 1 bunch gamma	Clams 1 bushel microwave	Cheese 1 slice visible ROY	Celery 1 stalk ultraviolet	Eggs 1 dozen visible ROY	Barley 1 stalk visible GBIV
Chicken Noodle 16 oz infrared	Wheat flour 2 lbs visible GBIV	Shrimp Cocktail microwave	Rigatoni 1 bite x-rays	Chicken 1 lb radio	Apple 1 bushel gamma	Cucumber 1 plant ultraviolet	Macaroni 1 bowl x-rays

 Answers

WARM-UP

Meat radio	Seafood microwave	Soup infrared	Dairy Visible ROY	Breads Visible GBIV	Vegetables ultraviolet	Pasta x-rays	Fruit gamma
Beef 0.25 lb	Shrimp cocktail	Tomato Soup 8 oz	Cheese 1 slice	Rye 1 loaf	Beans 5 pods	Rigatoni 1 bite	Grapes 1 twig
Pork 0.5 lb	Salmon steak	Chicken Noodle 16 oz	Eggs 1 dozen	Barley 1 stalk	Cucumber 1 plant	Macaroni 1 bowl	Bananas 1 bunch
Chicken 1.0 lb	Clams 1 bushel	Stew 32 oz	Milk 1 gallon	Wheat flour 2 lbs	Celery 1 stalk	Spaghetti 1 pot	Apple 1 bushel

What guidelines did you use to make your Periodic Table of Foods? How did you determine “Groups”?

Food groups & EM radiation order

How did you determine “Periods” or “Rows”?

Amounts within each food group

How was the periodic table developed and how is it arranged?

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

In 1829, a German chemist, J. W. Dobereiner, published a classification system. He grouped known elements into triads, sets of three elements with similar properties.

One triad consisted of chlorine, bromine, and iodine.

They each look different, but have very similar chemical properties.

Dobereiner's Triads

When the 3 elements in a triad are put in the order of their atomic masses, the difference in mass between the first and second elements is about the same as the difference in mass between the second and third elements.

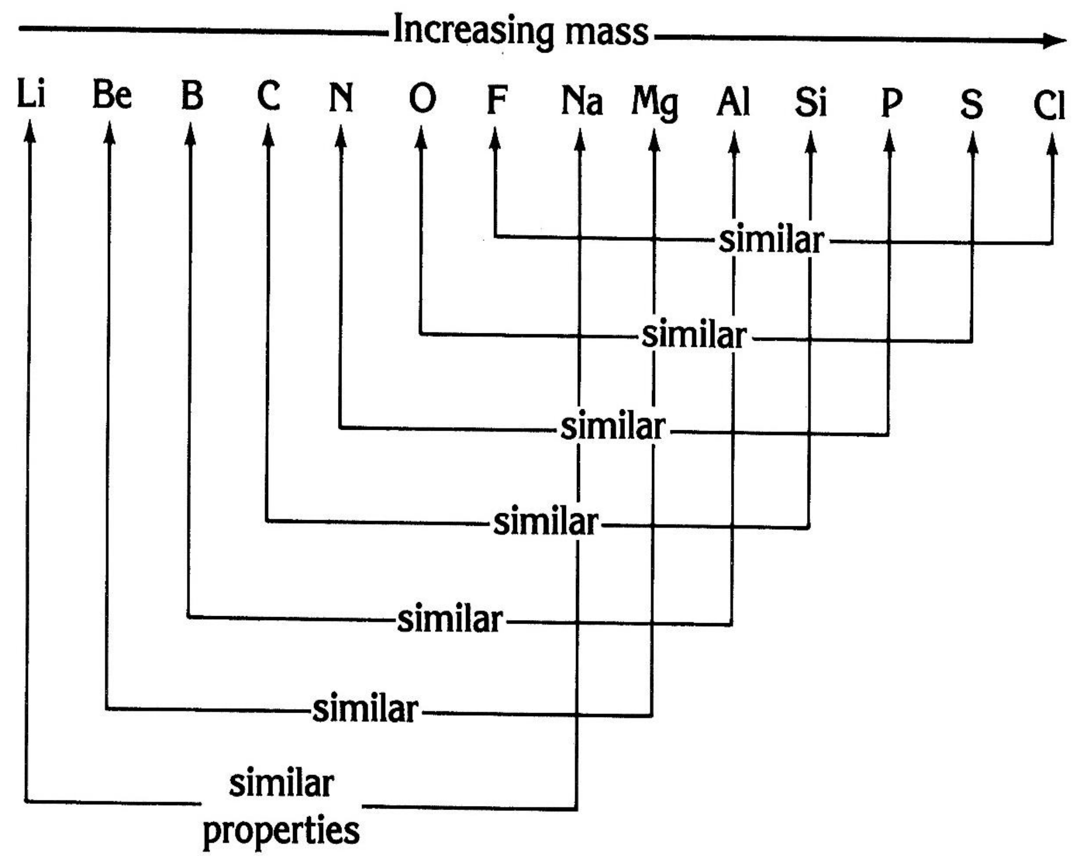
Example	Triad	Atomic Mass	Difference in Mass
1	chlorine	35.5	
	bromine	80	44.5
	iodine	127	47
2	sulfur	32	
	selenium	79	47
	tellurium	128	49
3	calcium	40	
	strontium	88	48
	barium	137	49
4	lithium	7	
	sodium	23	16
	potassium	39	16

Newland's Law of Octaves

John Newlands (1865)

He arranged the Periodic Table according to increasing atomic mass.

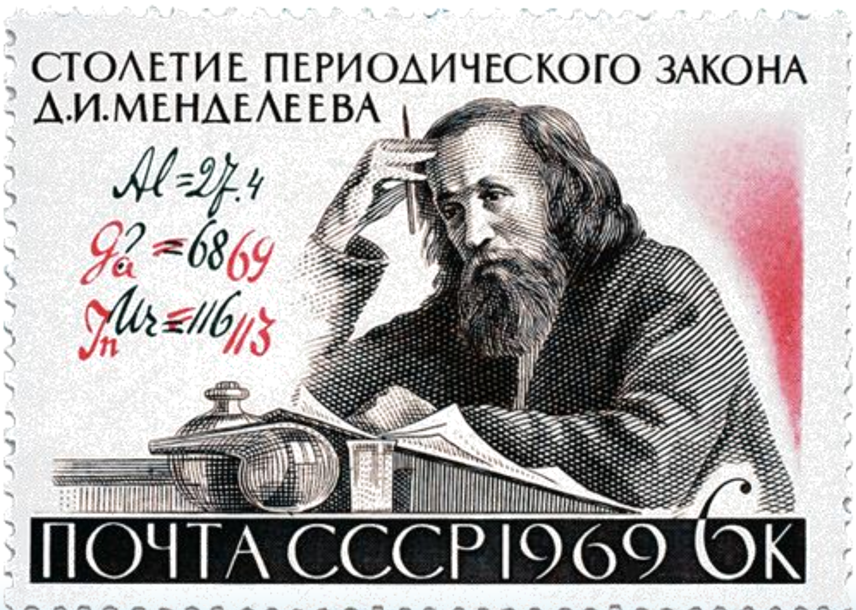
*He established the "**Law of Octaves**" → noticing a repeating pattern of similar properties every eight elements on the Periodic table.*



In 1869, the Russian chemist Dmitri Mendeleev produced the first orderly arrangement, or periodic table, of all 63 elements known at the time.

Mendeleev wrote the symbol for each element, along with the physical and chemical properties.

Mendeleev arranged the elements in order of increasing atomic mass.

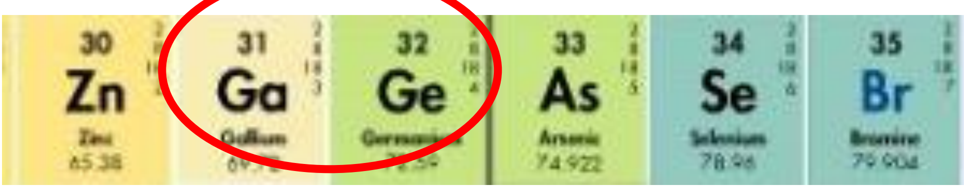


Mendeleev's Periodic Table

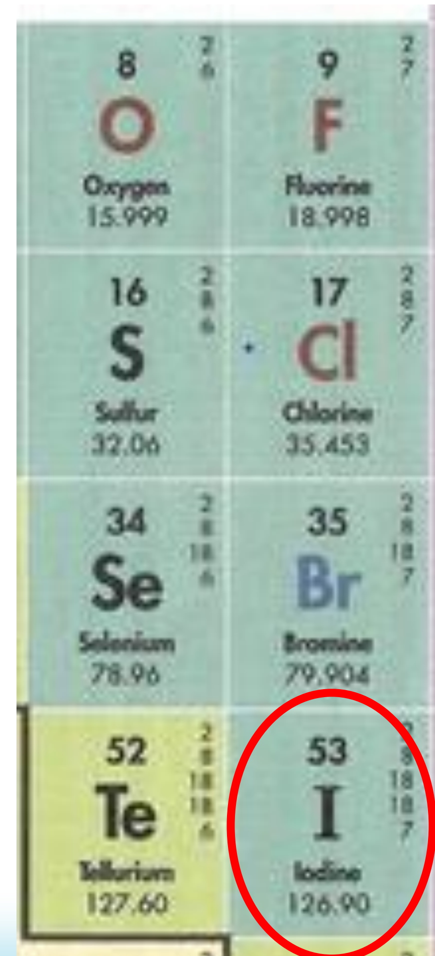
Mendeleev noticed that similar properties of elements occurred after "**periods**" of varying lengths (rows on Periodic Table).

He established "Families" or "**Groups**" (*columns*) on the Periodic Table, possessing similar chemical properties.

Mendeleev predicted properties and masses of **unknown elements** that he knew existed. (e.g. scandium, gallium, germanium).



Mendeleev could NOT account for Iodine whose atomic mass was less than Tellurium, but whose chemical properties belonged with Br and Cl's group .



The Modern Periodic Table

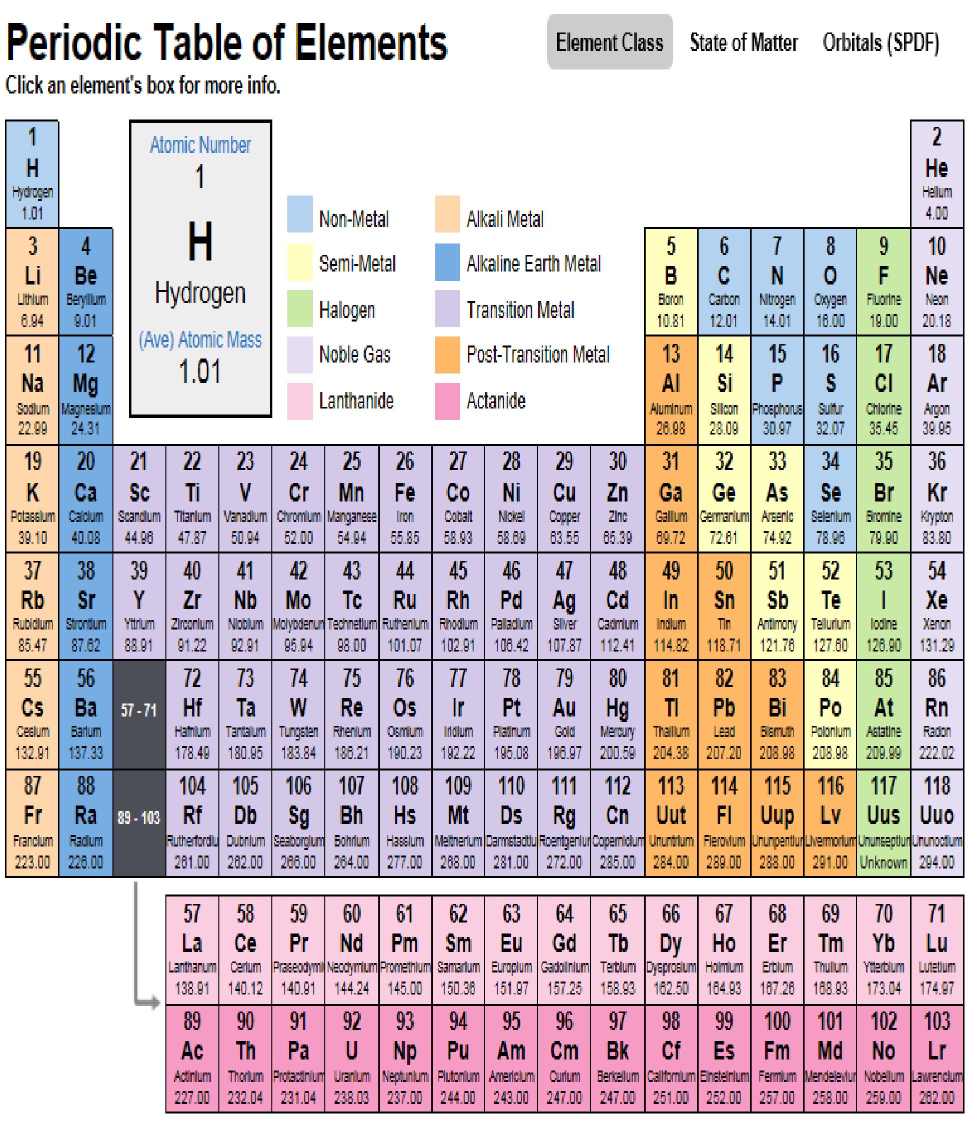
Henry Moseley (1887-1915)

- Contributed to the modern version of the periodic table.
- Arranged all the elements in order of increasing atomic number.
- Accounted for variations resulting from isotopes.

The Modern Periodic Table

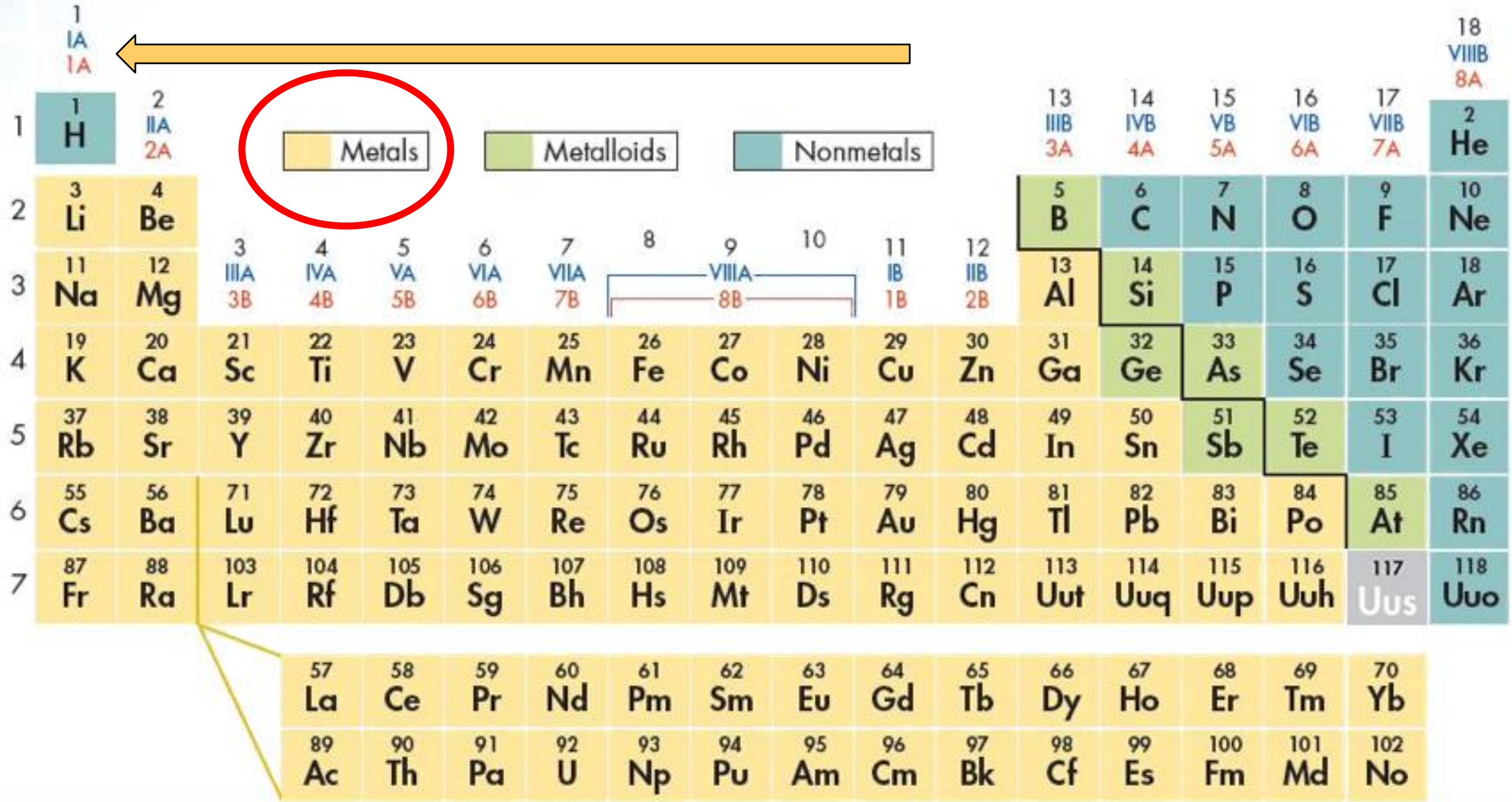
The **periodic table** of elements is an organized display of the chemical elements.

- In order of increasing **atomic number** (protons)
- **Similarities** in chemical **properties**
  - Similarities in **electron configurations**



Metals

As one goes across a period, the properties of elements become less metallic and more nonmetallic. About 80% of the elements are metals.

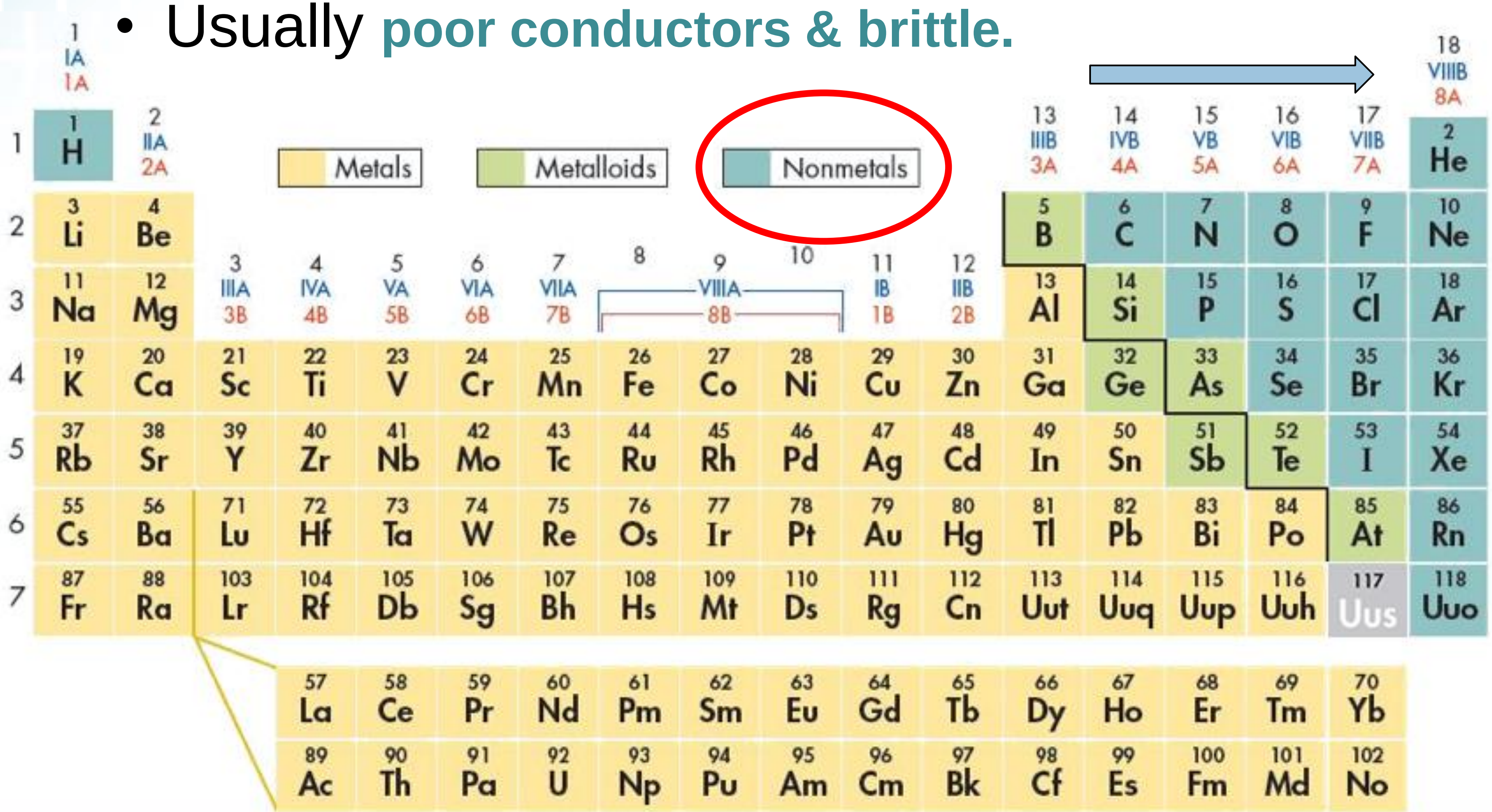


Metals

- Good conductors of heat and electric current.
- High **luster**, or sheen … ability to reflect light.
- Solids at room temperature, except for mercury (Hg).
- **Ductile**, can be drawn into wires.
- **Malleable**, can be hammered into thin sheets without breaking.
- **Hard & Strong**

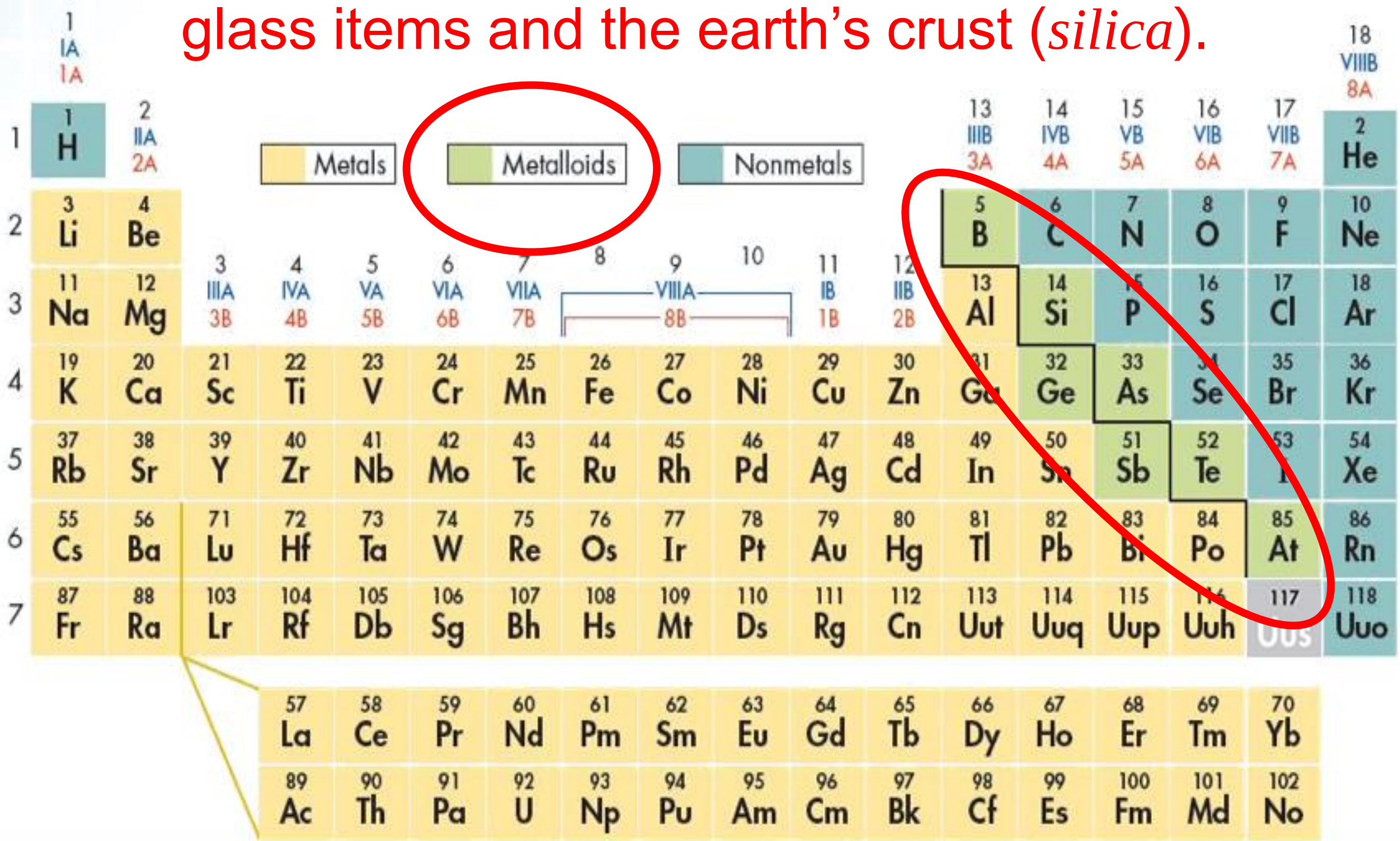
Nonmetals

- Tend to have properties opposite of metals.
- Usually **poor conductors & brittle.**

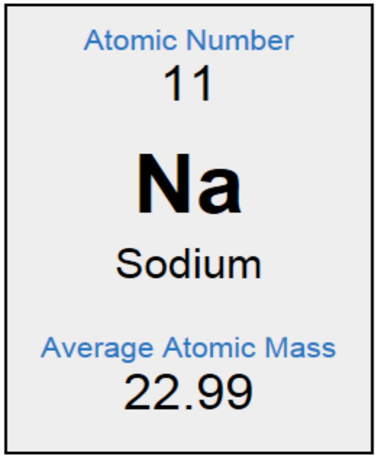


Metalloids

- "Staircase Elements" that sometimes behave like metals.
- Under other conditions, they may behave like nonmetals.
- Silicon is also present as the compound silicon dioxide in glass items and the earth's crust (*silica*).

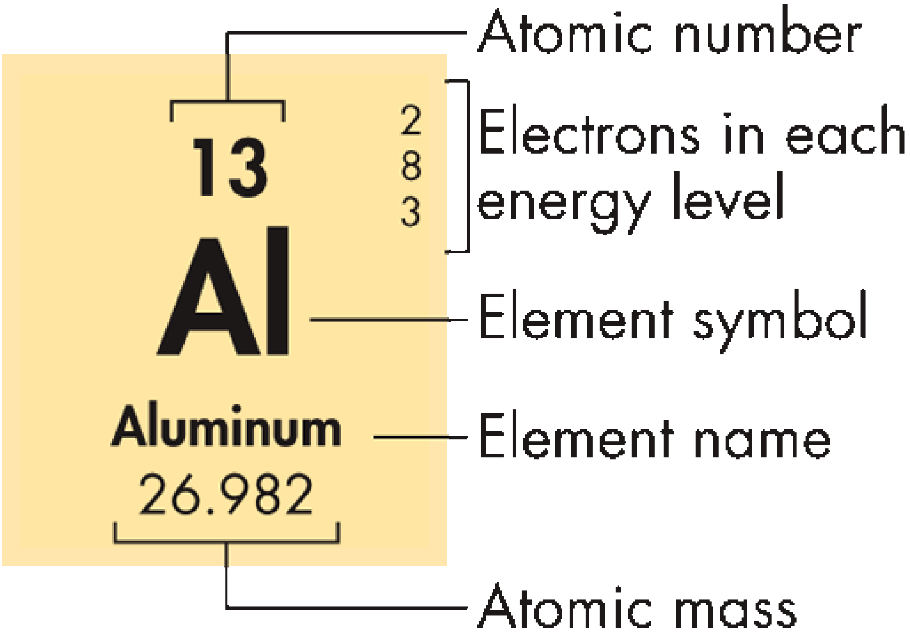


Information for Each Element

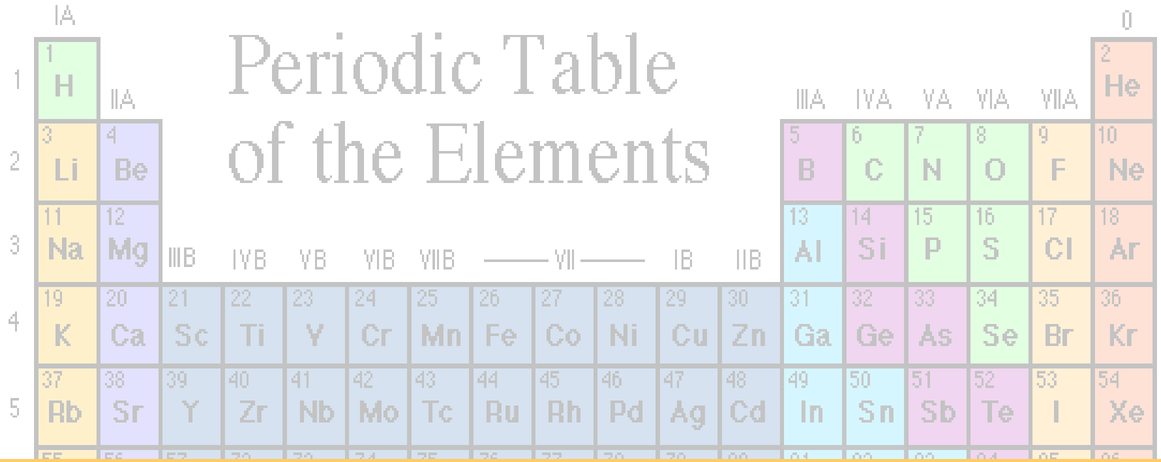


Each element's entry on the periodic table shows:

- Chemical symbol
- Element name
- Atomic number
- Average atomic mass
- Electron configuration

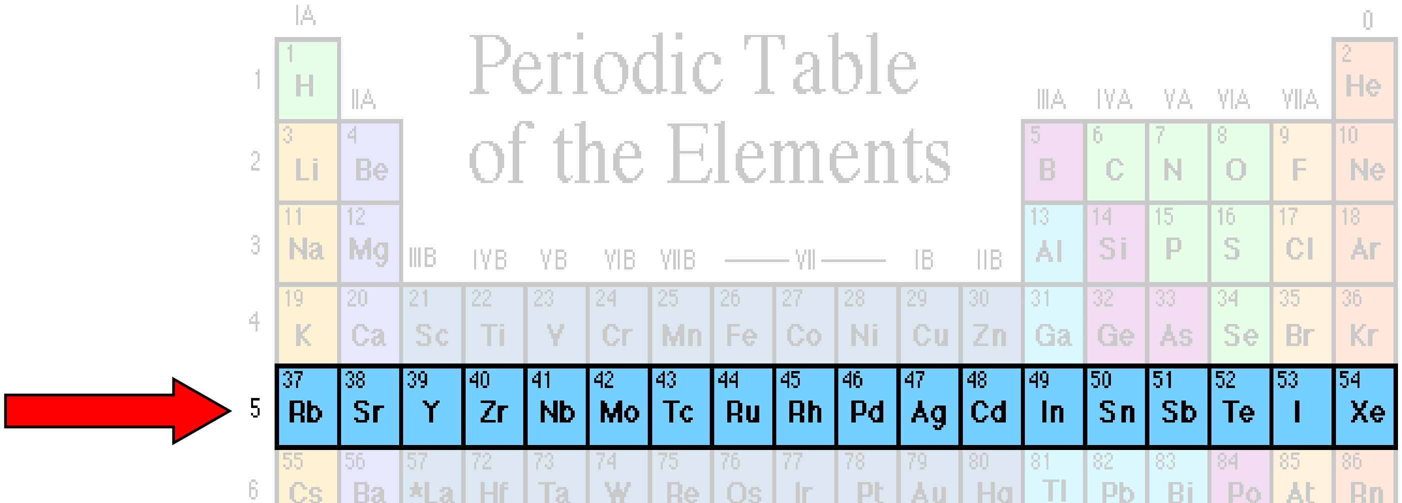


Periodic Law



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

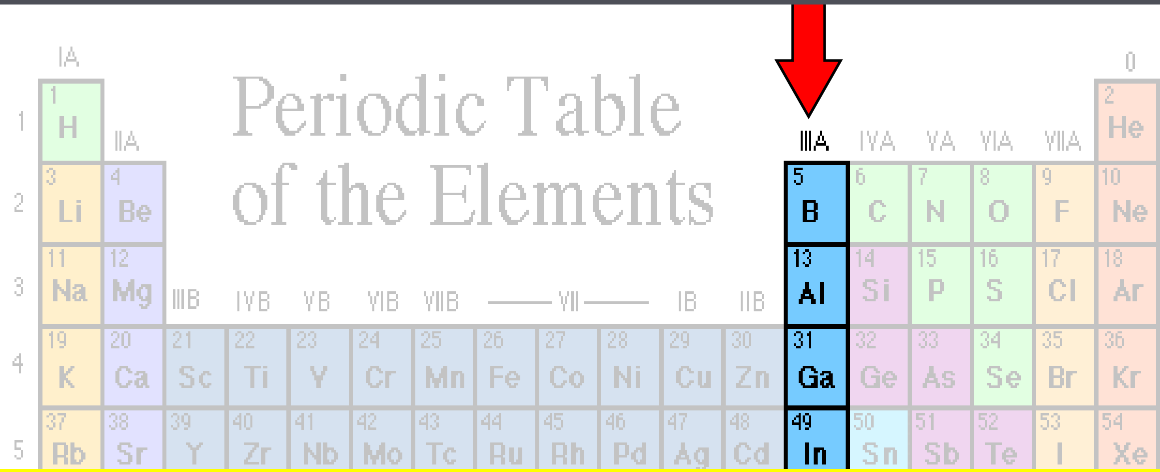
Periods



Horizontal rows on the periodic table

- Indicate <u>**principal energy level**</u> of valence electrons (Quantum number 1, n).
- Atomic number increases from left to right across the period.
- In each period the number of <u>**valence**</u> electrons increases from left to right.
- Chemical properties change systematically across the periodic table.

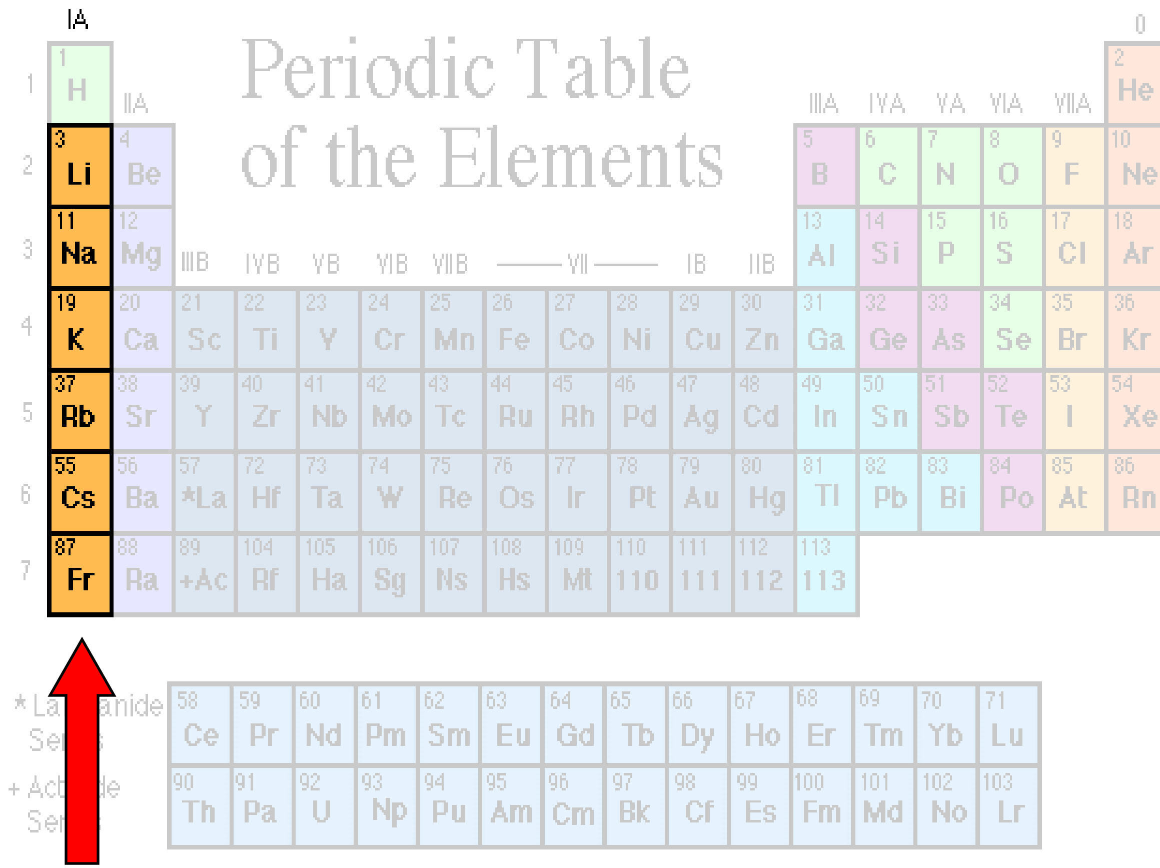
Groups or Families



Groups: columns or **families** on the periodic table

- Elements within a group have the same chemical properties.
- Groups contain the same number of electrons in outermost level (<u>**valence**</u> electrons), which explains why groups have the same properties.
- "A" groups → electrons filling s and p valence orbitals.

Magic number is "8" … s2 + p6



S^1

valence

Alkali Metals

Alkali Metals (Group IA)

- Group 1 or IA
- Easily lose an electron to form a **+1 cation** *in order to gain ideal electron configuration*
- Typical properties:
  - Silver in color
  - Soft (can be cut with a knife)
  - Highly reactive with oxygen and water
  - Able to oxidize in air

Alkali Metals (Group IA)

- Group 1 or IA
- Easily lose an electron to form a +1 cation *in order to gain ideal electron configuration*

$_{11}Na^{23}$

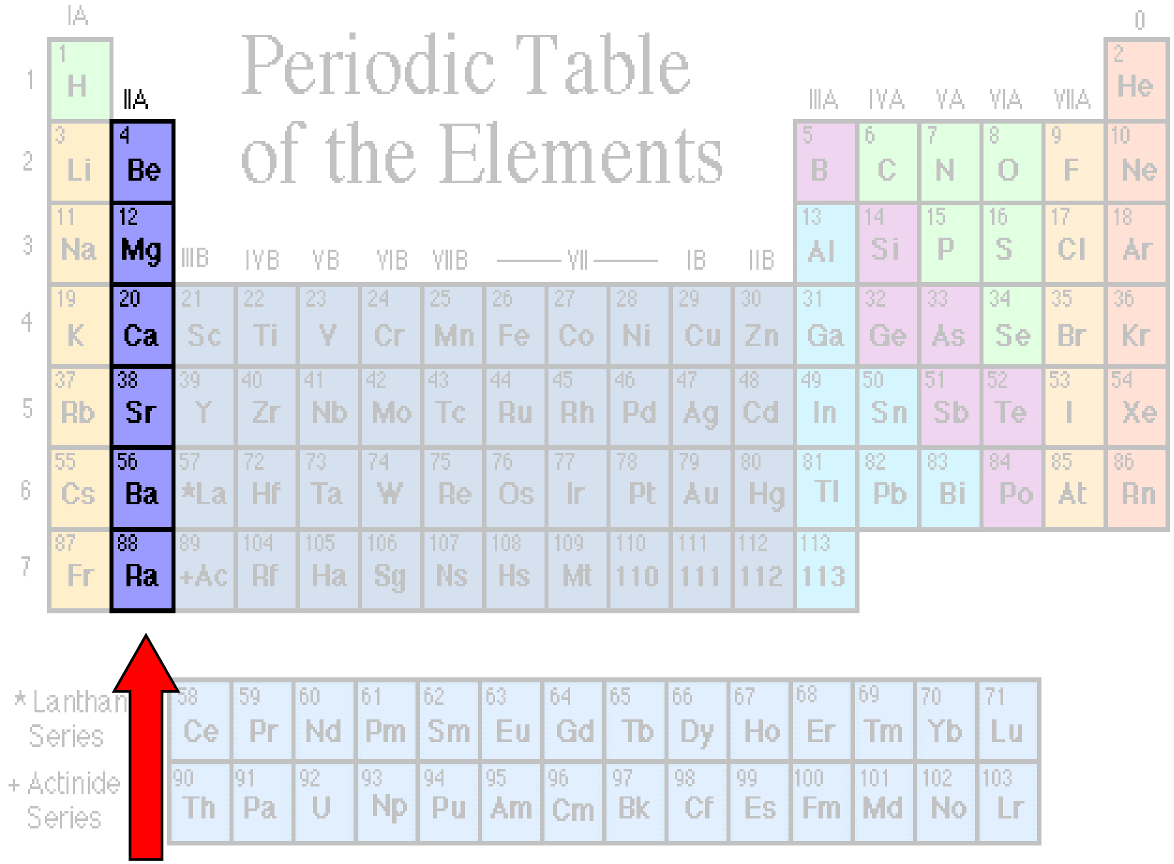
+11 p
-11 e
0

$1s^2\ 2s^2\ 2p^6\ \mathbf{3s^1}$

- **"Magic number is "8" … s2 + p6**
- *Is it easier for the metals to gain 7 electrons to make 8 or to lose 1 electron to have a full valence in the next lowest energy level?*

+11 p
-10 e

+1 charge



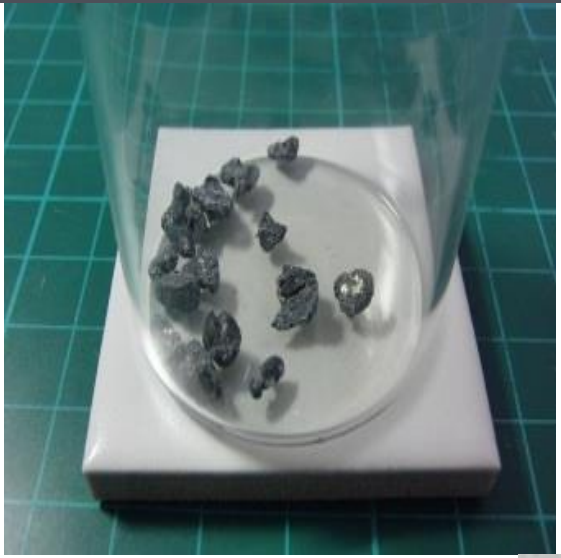
S^2

valence

Alkaline Earth Metals

Alkaline Earth Metals (Group IIA)

- Group 2 or IIA
- Lose two electrons to form a **+2 cation** *in order to gain ideal electron configuration*
- Typical properties:
  - Silver in color
  - More brittle than alkali metals
  - Somewhat reactive
  - Low in density, with low melting and boiling points



Alkaline Earth Metals (Group IIA)

- Group 2 or IIA
- Lose two electrons to form a **+2 cation** *in order to gain ideal electron configuration*
- **"Magic number is "8" … s2 + p6**
- *Is it easier for the metals to gain 6 electrons to make 8 or to lose 2 electron to have a full valence in the next lowest energy level?*

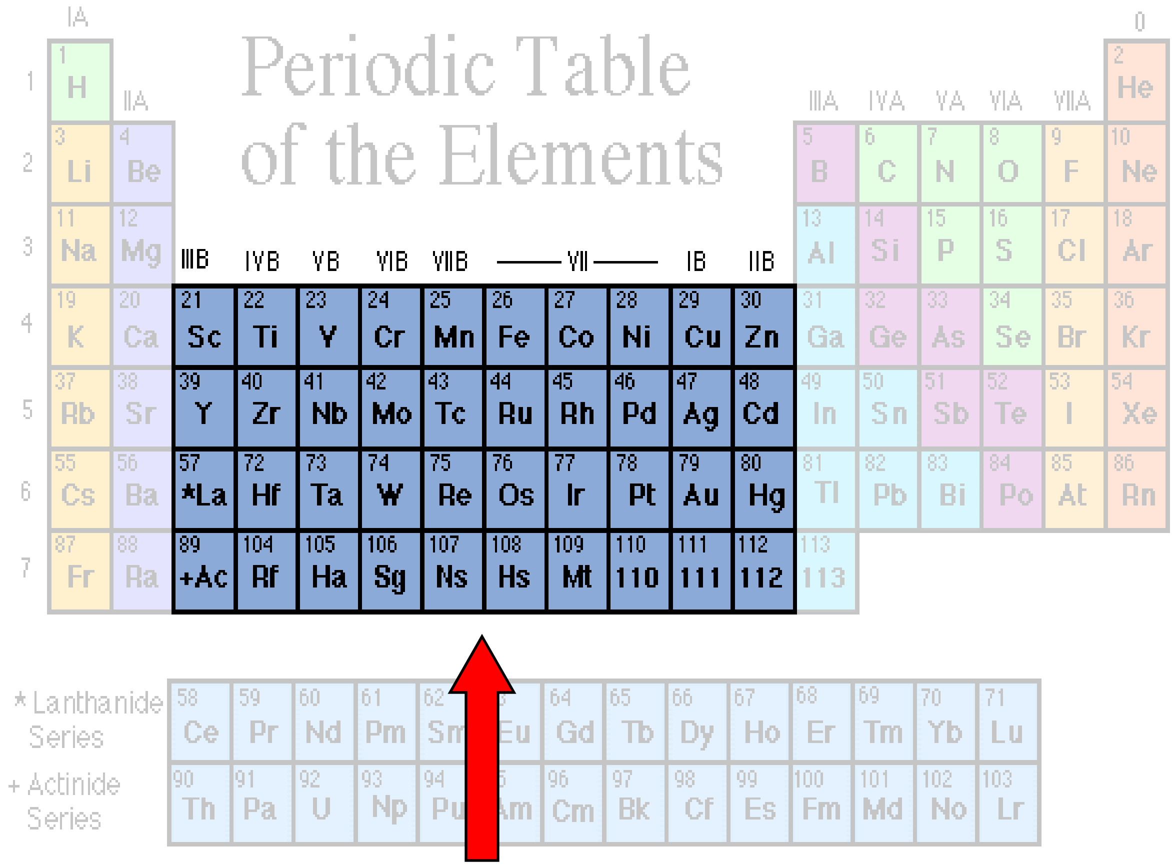
$_{12}Mg^{24}$

+12 p
-12 e
0

$1s^2\ 2s^2\ 2p^6\ \mathbf{3s^2}$

+12 p
-10 e

+2 charge



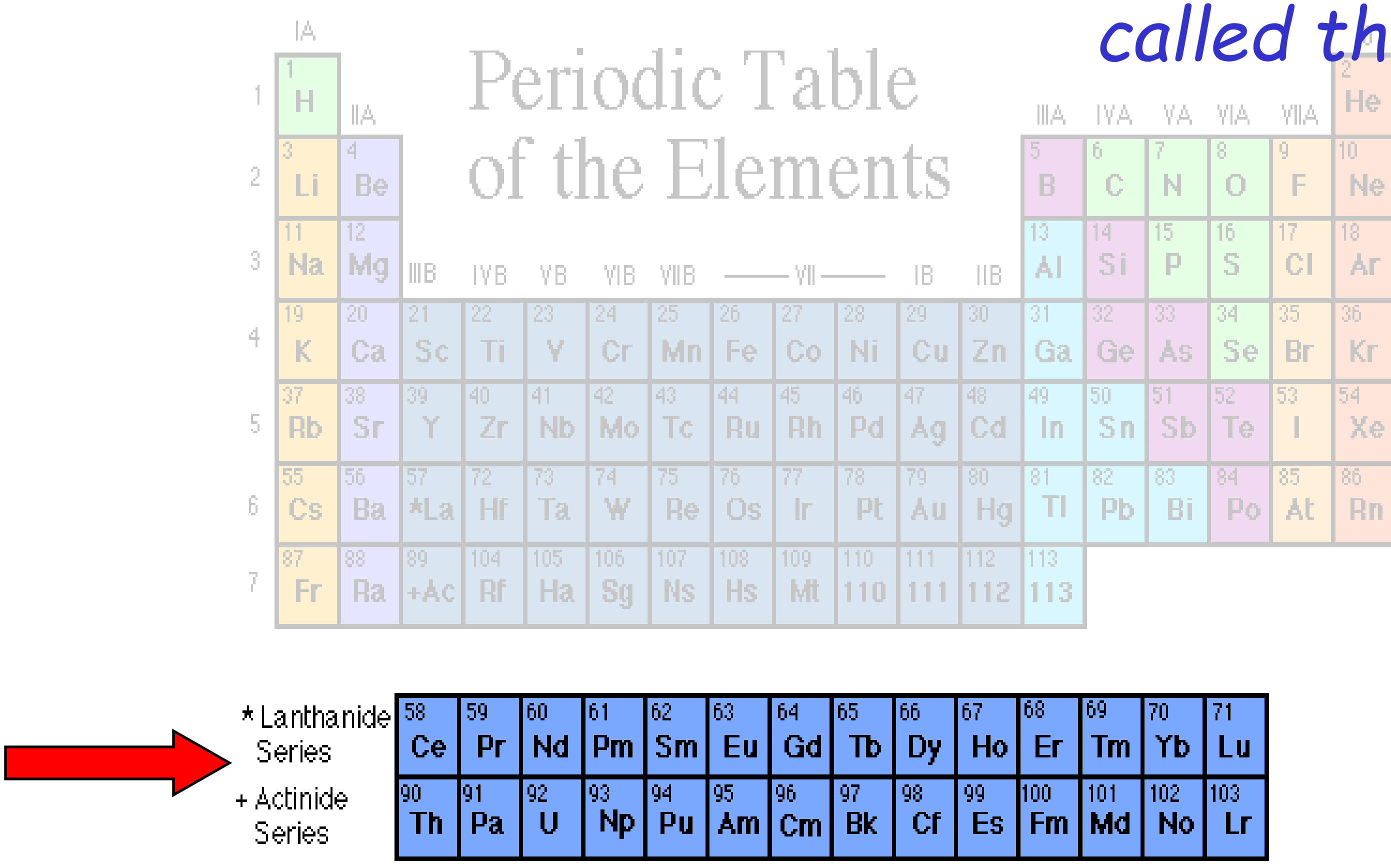
B Groups

Transition Metals

Transition Metals (B Groups)

- Characterized by the presence of electrons in d orbitals
- E.g. Copper, silver, gold, iron
- Form colored compounds
- May have unusual properties:
  - Magnetism
  - High conductivity

These elements are also called the rare-earth elements.

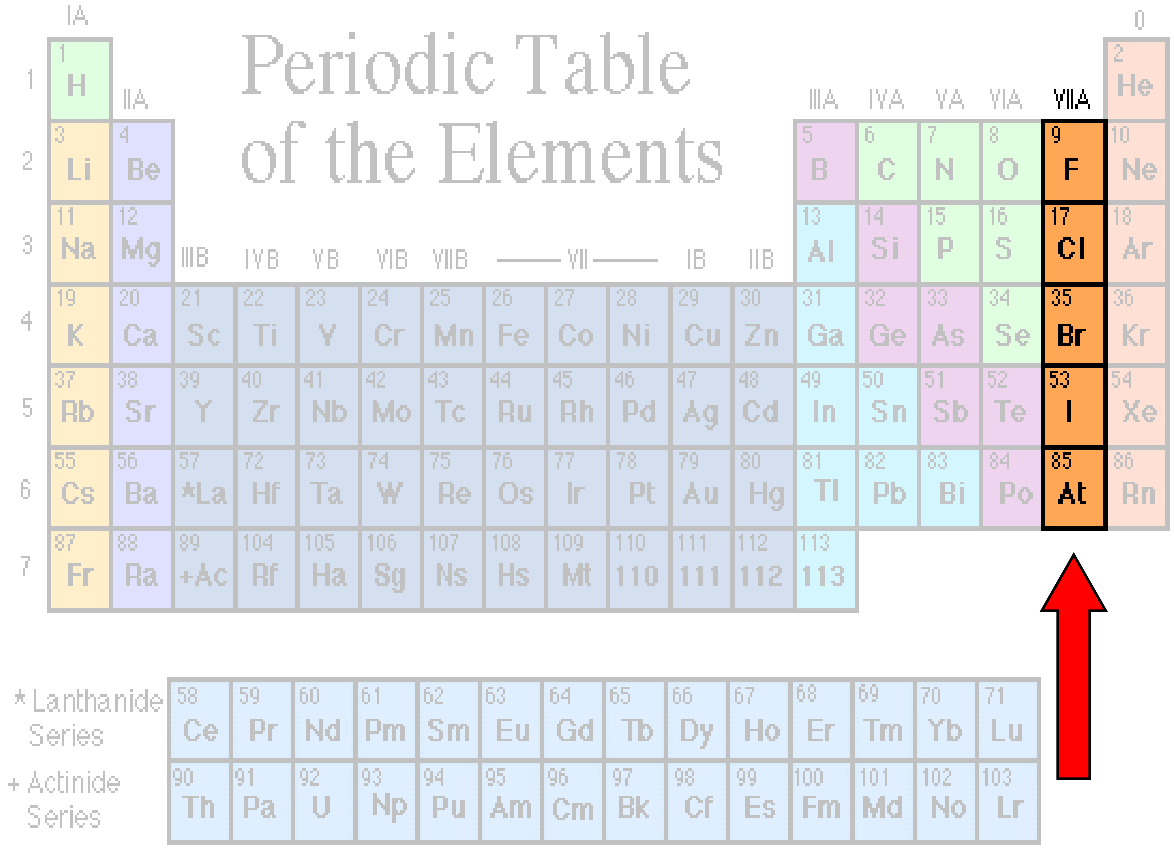


B Groups

InnerTransition Metals

Inner Transition Metals (B Groups)

- Characterized by the presence of electrons in f orbitals
- **Lanthanides**: *elements 57-71*
- **Actinides**: *elements 89-103*
- Radioactive (e.g. U-92)
- Present in only trace amounts on Earth



S^2p^5

valence

Halogens

Halogens (Group VIIA)

- Group 17 or VIIA
- Easily gain an electron to form a **–1 anion** *in order to gain ideal electron configuration*
- Typical properties
  - Highly reactive with metals
  - Toxic to organisms
  - Most occur as diatomic molecules (F_2, Cl_2, Br_2, I_2)
  - React with metals to form salts

Halogens (Group VIIA)

- Group 17 or VIIA
- Easily gain an electron to form a –1 anion *in order to gain ideal electron configuration*
- **"Magic number is "8" … s2 + p6**
- *Is it easier for the non-metal to gain 1 electron to make 8 or to lose 7 electrons to have a full valence in the energy level?*

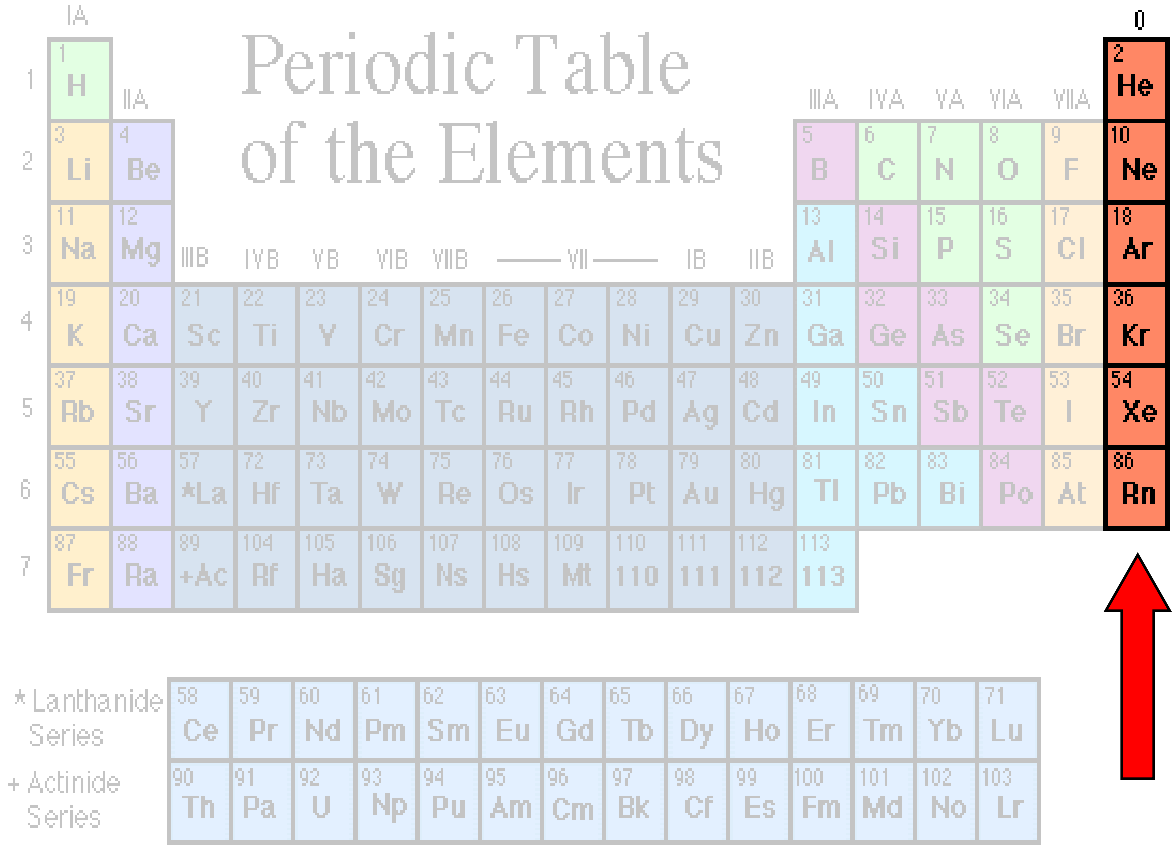
$_{17}Cl^{35}$

+17 p
-17 e
0

$1s^2\ 2s^2\ 2p^6$ **$3s^2\ 3p^5$**

+17 p
-18 e

-1 charge



S^2p^6 valence

Noble Gases

Noble Gases (Group VIIIA)

- Group 18 or VIIIA
- Inert gases (nonreactive)
  have ideal electron configuration
- Typical properties
  - Odorless and tasteless
  - Nonreactive and nonflammable
  - Have extremely low boiling points (i.e. gases)
  - Produce characteristic colors when excited electrically

Songs

The Periodic Table Song (2:44)

http://somup.com/cF6QFinnyQ

Tom Lehrer (1970 … 1:47)

The Elements Song

http://somup.com/cFQ22hVSKJ

Octet Rule – Stability of Atoms When Bonding

The stability of an atom is associated with electron configuration:

The maximum number of electrons in outer level is $8e^-$
[***s*** orbital holds up to 2 e^-,
p orbitals hold up to 6 e^-]

8e- represents a very stable arrangement (noble gas configuration)

Helium ($_2He^4$) has only 2e- but a complete outer shell.

Atoms tend to combine with other atoms in such a way that each atom has eight electrons in its valence shell, giving it the same electron configuration as a noble gas.

Valence Electrons

The number of electrons in the highest occupied energy level (n) level (valence electrons.)

Lithium (Li)	$1s^2 2s^1$
Sodium (Na)	$1s^2 2s^2 2p^6 3s^1$
Potassium (K)	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

Carbon (C)	$1s^2 2s^2 2p^2$
Silicon (Si)	$1s^2 2s^2 2p^6 3s^2 3p^2$

Helium (He)	$1s^2$
Neon (Ne)	$1s^2 2s^2 2p^6$
Argon (Ar)	$1s^2 2s^2 2p^6 3s^2 3p^6$
Krypton (Kr)	$1s^2 2s^2 2p^6 3s^2 3p^6 2d^{10} 4s^2 4p^6$

Kernel & Valence Electrons in A Groups

Example:

Phosphorus (P)

$1s^2 2s^2 2p^6$ | $3s^2 3p^3$

Core kernel

- Highest n orbitals = **valence electrons**

Kernel & Valence Electrons in A Groups

Example:

Phosphorus (P)

$1s^2 2s^2 2p^6$ | $3s^2 3p^3$

[Ne] | $3s^2 3p^3$

Core kernel | **valence**

- Highest n orbitals = **valence electrons.**
- All other orbitals = **kernel electrons (use [Ne]).**
- Group number relates to the number of valence electrons.
- Noble gases (group VIII or 18): full valence shell.

Kernel & Valence Electrons in B Groups

Examples:

Cobalt (Co)

$1s^2 2s^2 2p^6 3s^2 3p^6$ $4s^2 3d^7$

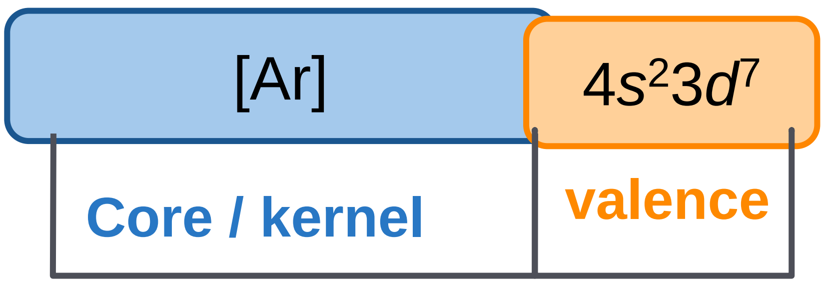
Core / kernel **valence**

- *NOTICE that valence electrons are still in the highest "n"* s and p orbitals.
- Partially filled *d* and *f* orbitals = valence electrons

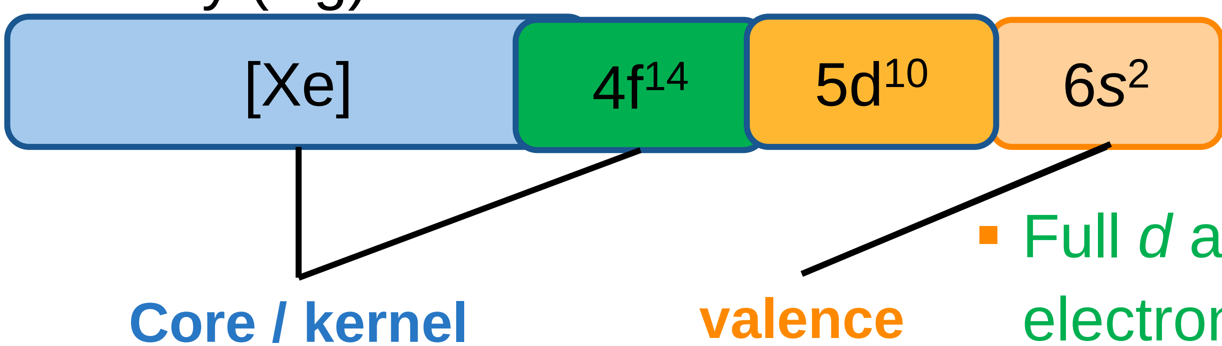
Core and Valence Electrons in B Groups

Examples:

Cobalt (Co)

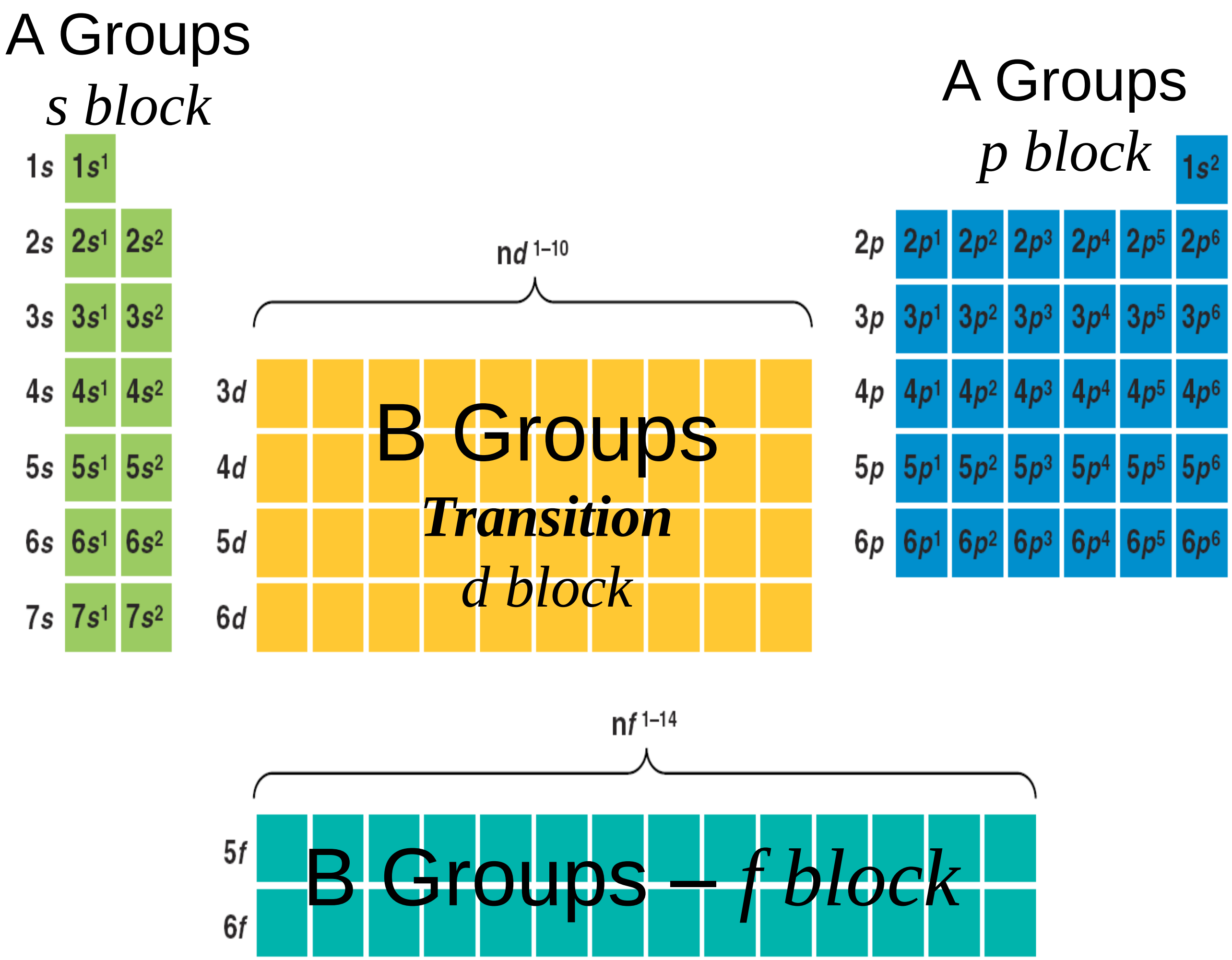


Mercury (Hg)



- *NOTICE that valence electrons are still in the highest "n"* *s* and *p* orbitals
- Partially filled *d* and *f* orbitals = valence electrons
- Full *d* and *f* orbitals = Core electrons

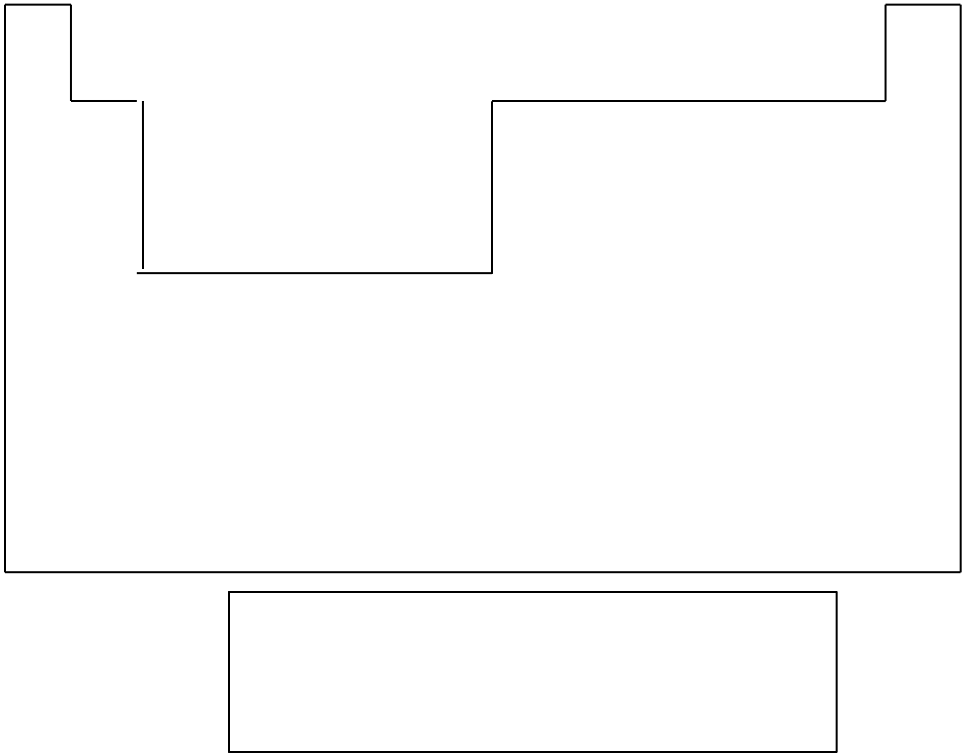
Group “A” & “B” Elements distinguished by sublevels



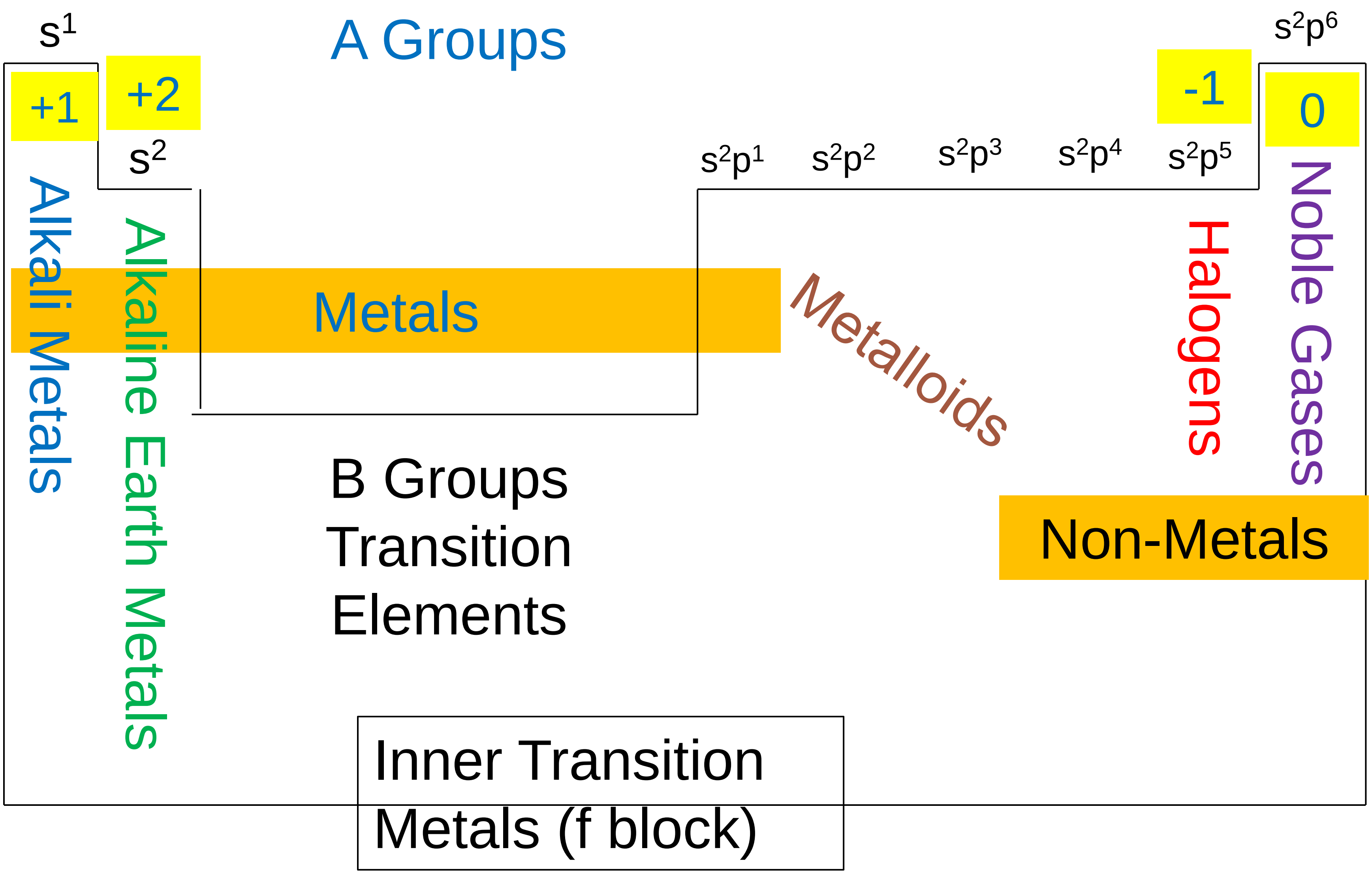
Review of the Periodic Table

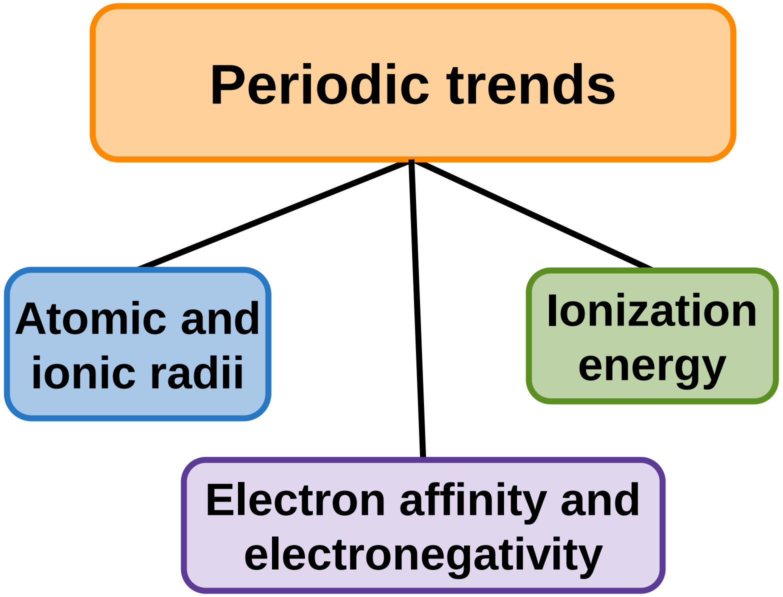
Copy the Blank table and LABEL

- A Groups with valence electron configuration
- B Groups (transition elements, inner transition)
- Metals, non-metals, metalloids
- Alkali & Alkaline Earth Metals, Halogens, Noble Gases
- What ion would the major groups form?



Review of the Periodic Table



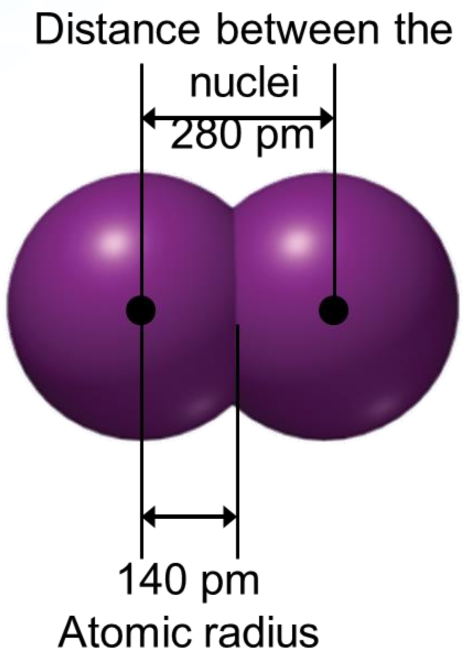


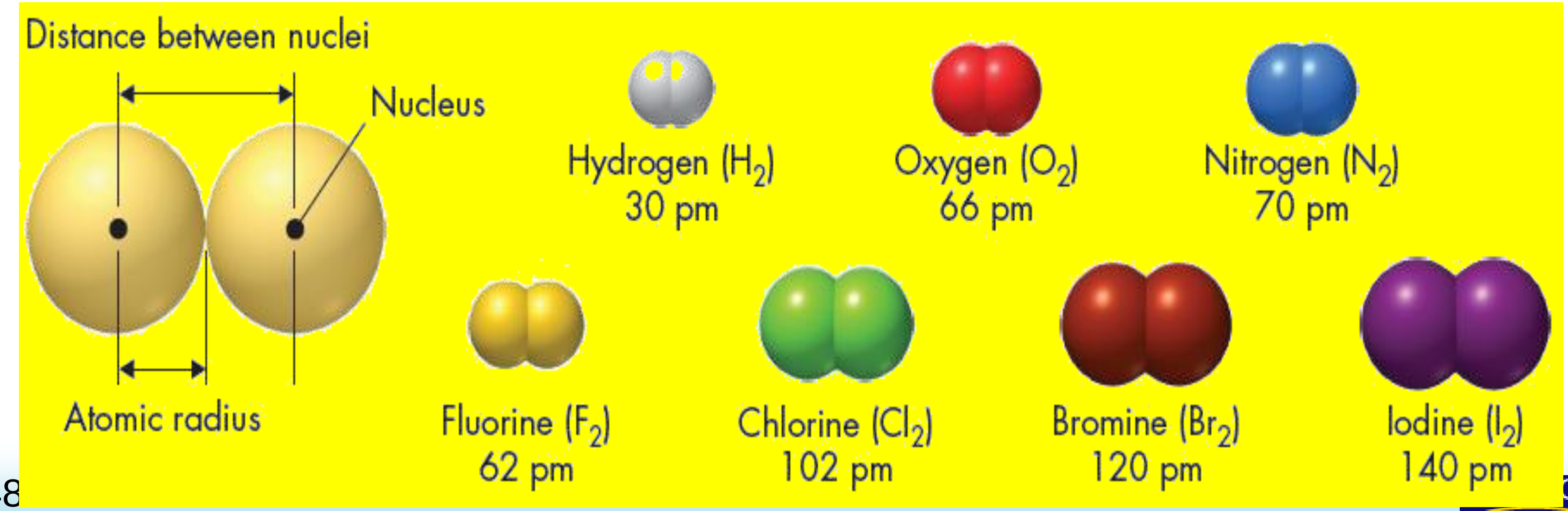
What **trends** become apparent from the arrangement of electrons in the periodic table?

LESSON SUMMARY

Atomic Radii (Size)

This size is expressed as an atomic radius, and is one-half of the distance between the nuclei of two atoms of the same element when the atoms are joined. (picometers or 10^{-12} m)

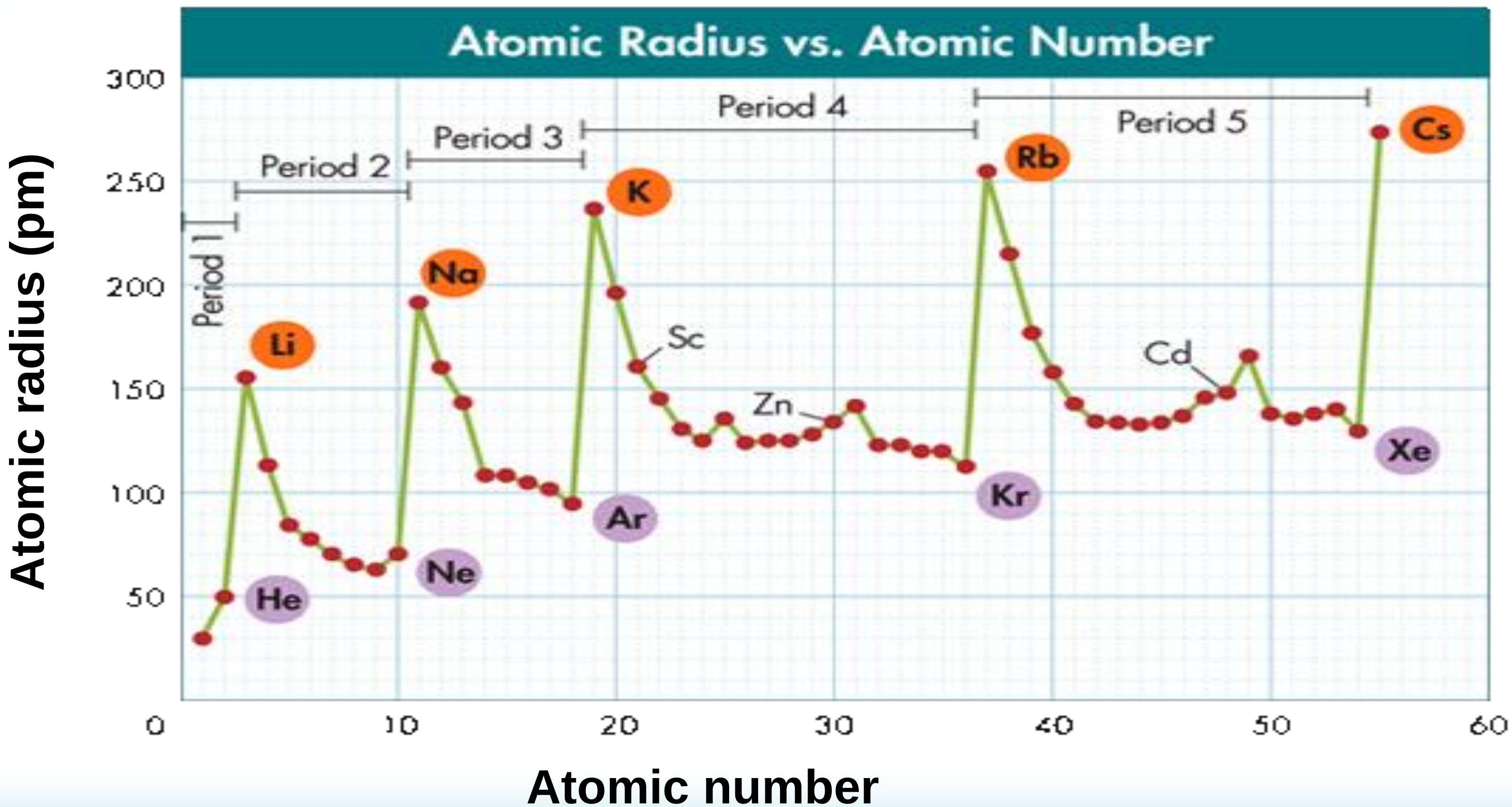




Trends in Atomic Size

In general, atomic size

- decreases from left to right across a period.
- increases going down a group.



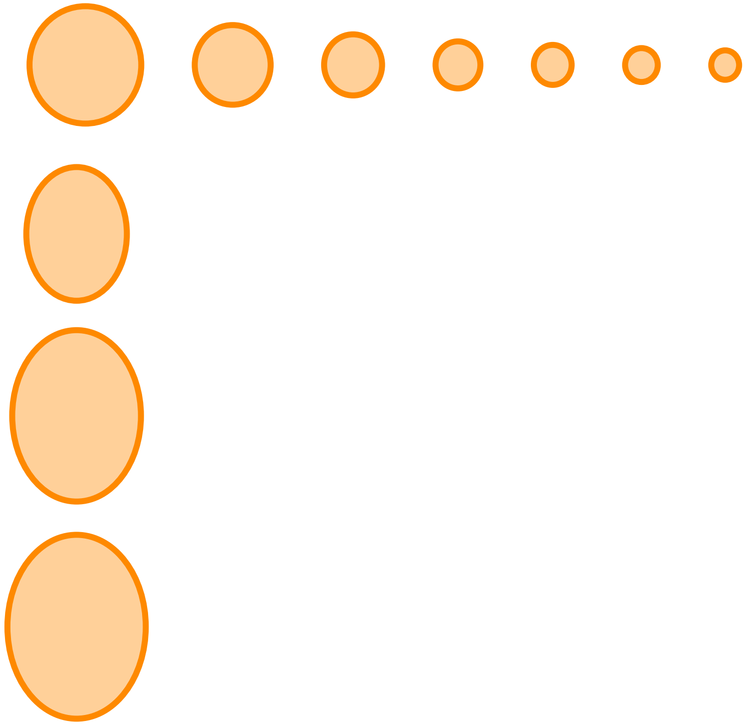
Trends of Atomic Radii

Electrons are added:

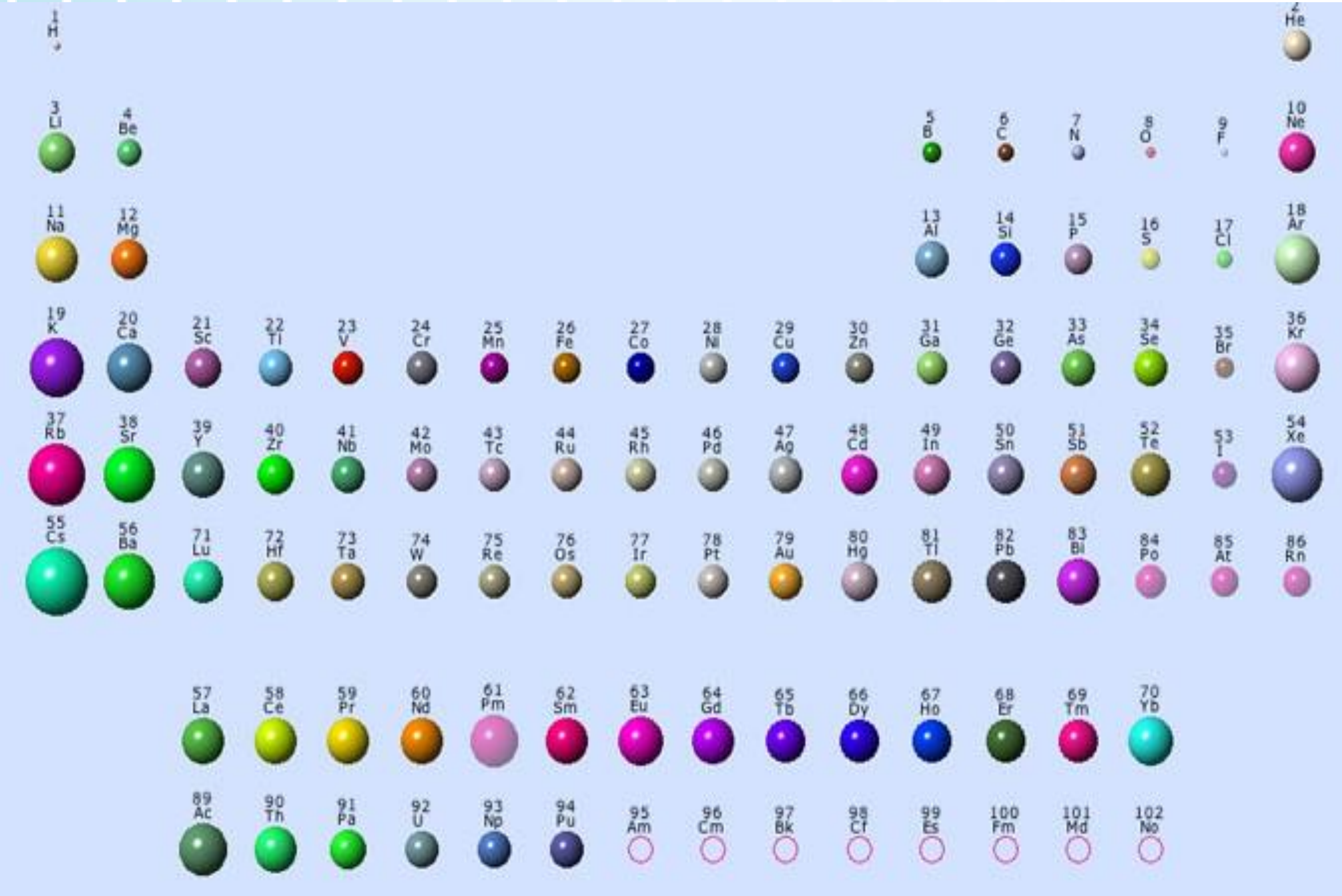
- To the same energy level across a period (*stronger nuclear charge draws them in*).
  - *E.g. using a larger magnet to pick up metals.*
- To a higher energy level down a group (*the atom is much larger and electrons more energetic*).
  - *E.g. placing the electrons in a bigger room to accommodate the larger atom.*

Atomic radii tend to:

- Decrease across a period.
- Increase down a group.

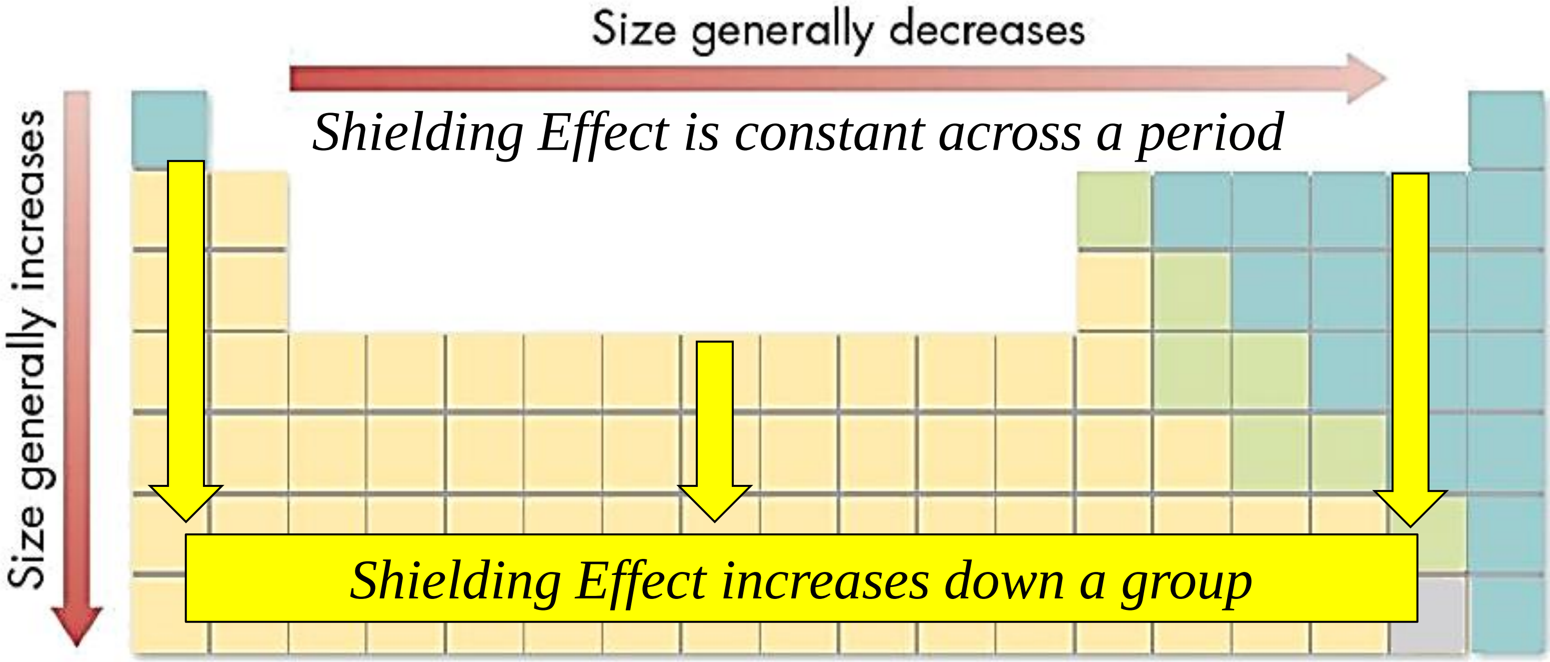


Trends in Atomic Size



The Shielding Effect

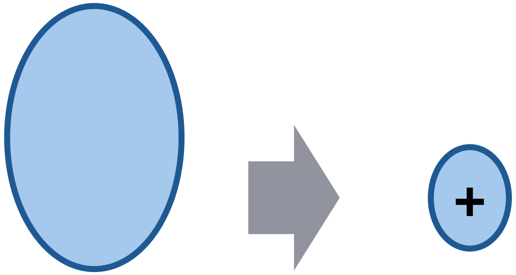
The increase in the number of occupied orbitals shields electrons in the highest occupied energy level from the attraction of protons in the nucleus (e.g. solar eclipse).



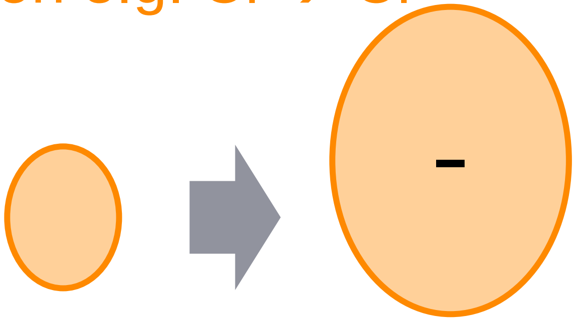
Trends of **Ionic Radii**

Ionic radius is a measure of the size of an ion.

Cation e.g. Na → Na^{+}



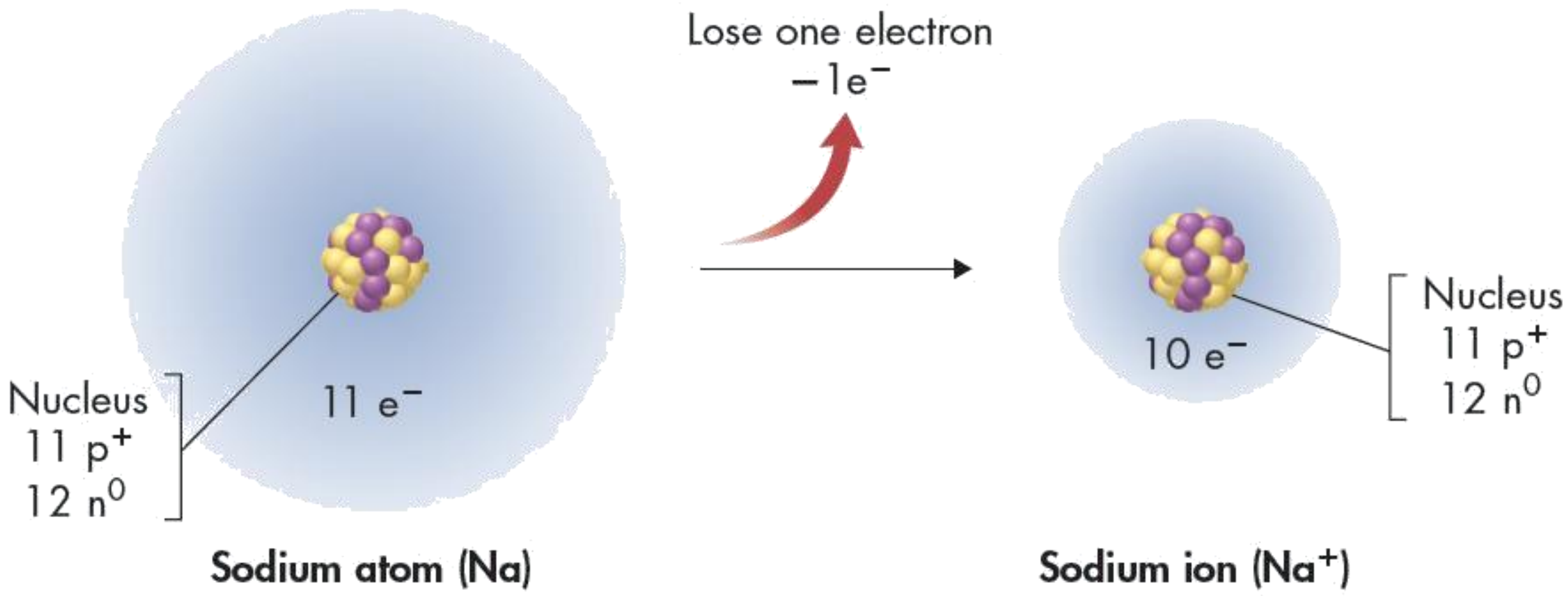
Anion e.g. Cl → Cl^{-}



- DECREASE for cations across a period.
  - *Groups 1A – 3A elements lose electrons to become cations.*
- INCREASE for anions across a period.
  - *Groups 4A – 8A elements gain electrons to become anions.*
- Increase down a group.

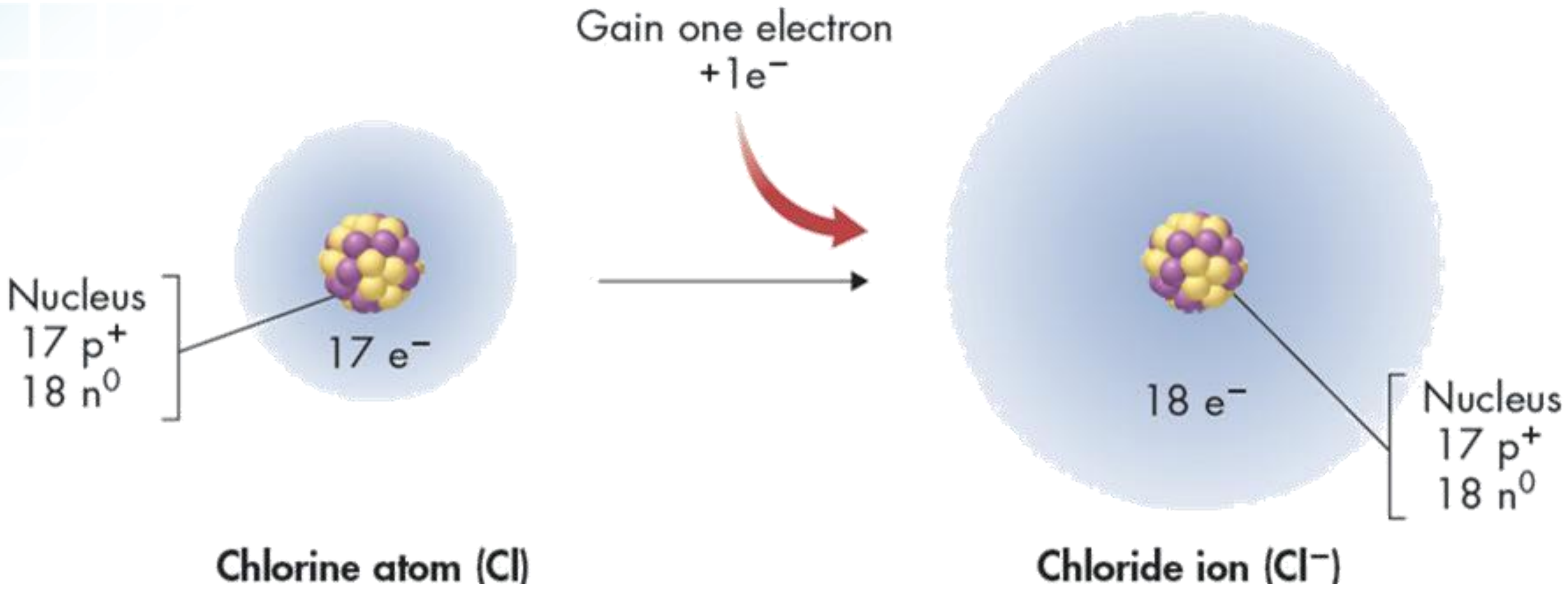
Ions

Metals, such as Sodium lose electrons when bonding, giving the sodium ion a net positive charge (11 protons - 10 electrons). The positive ion is called a **cation** and is written as Na^+. The ionic size is SMALLER than the atomic size.



Ions

Nonmetals, such as chlorine, *gain* electrons when bonding, producing an **anion** (negative ion): (+17 p – 18 e-). This is written: Cl^-. The ionic size is GREATER than the atomic size.



In general, metals tend to form cations. Nonmetals tend to form anions.

TRY IT

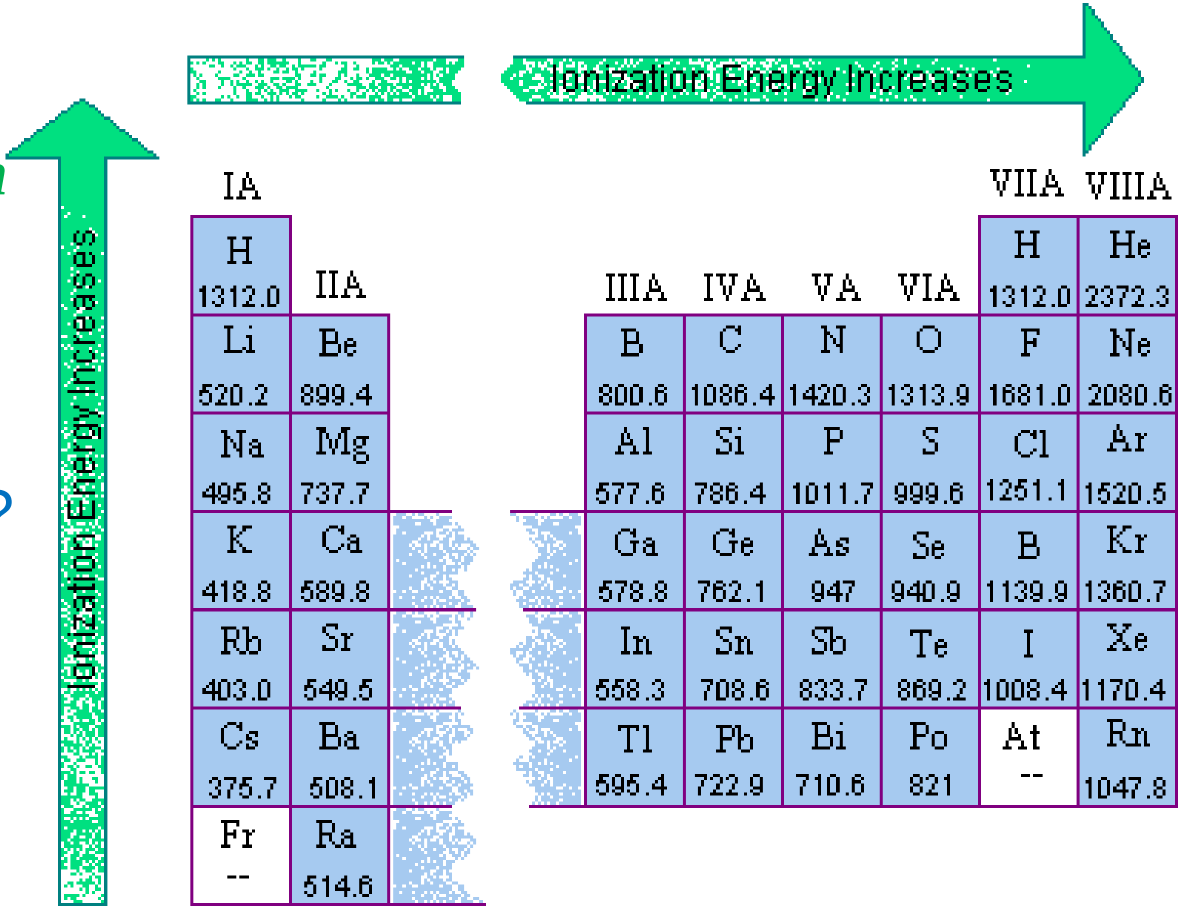
Ionization Energy

The energy required to remove an electron from an atom.

The **tendency to lose electrons** is evidence of **????** character (*to gain ideal electron configuration*).

The energy required to remove the first electron from an atom is called the first ionization energy.

Ionization energy ???? across a period & ???? down a group.



IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
H 1312.0						H 1312.0	He 2372.3
Li 520.2	Be 899.4	B 800.6	C 1086.4	N 1420.3	O 1313.9	F 1681.0	Ne 2080.6
Na 495.8	Mg 737.7	Al 577.6	Si 786.4	P 1011.7	S 999.6	Cl 1251.1	Ar 1520.5
K 418.8	Ca 589.8	Ga 578.8	Ge 762.1	As 947	Se 940.9	B 1139.9	Kr 1360.7
Rb 403.0	Sr 549.5	In 558.3	Sn 708.6	Sb 833.7	Te 869.2	I 1008.4	Xe 1170.4
Cs 375.7	Ba 508.1	Tl 595.4	Pb 722.9	Bi 710.6	Po 821	At --	Rn 1047.8
Fr --	Ra 514.6						

TRY IT

Ionization Energy

The energy required to remove an electron from an atom.

The **tendency to lose electrons** is evidence of **metallic** character (*to gain ideal electron configuration*).

The energy required to remove the first electron from an atom is called the first ionization energy.

Ionization energy increases across a period & decreases down a group.

Ionization Energy Increases

Ionization Energy Increases

IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA
H 1312.0						H 1312.0	He 2372.3
Li 520.2	Be 899.4	B 800.6	C 1086.4	N 1420.3	O 1313.9	F 1681.0	Ne 2080.6
Na 495.8	Mg 737.7	Al 577.6	Si 786.4	P 1011.7	S 999.6	Cl 1251.1	Ar 1520.5
K 418.8	Ca 589.8	Ga 578.8	Ge 762.1	As 947	Se 940.9	B 1139.9	Kr 1360.7
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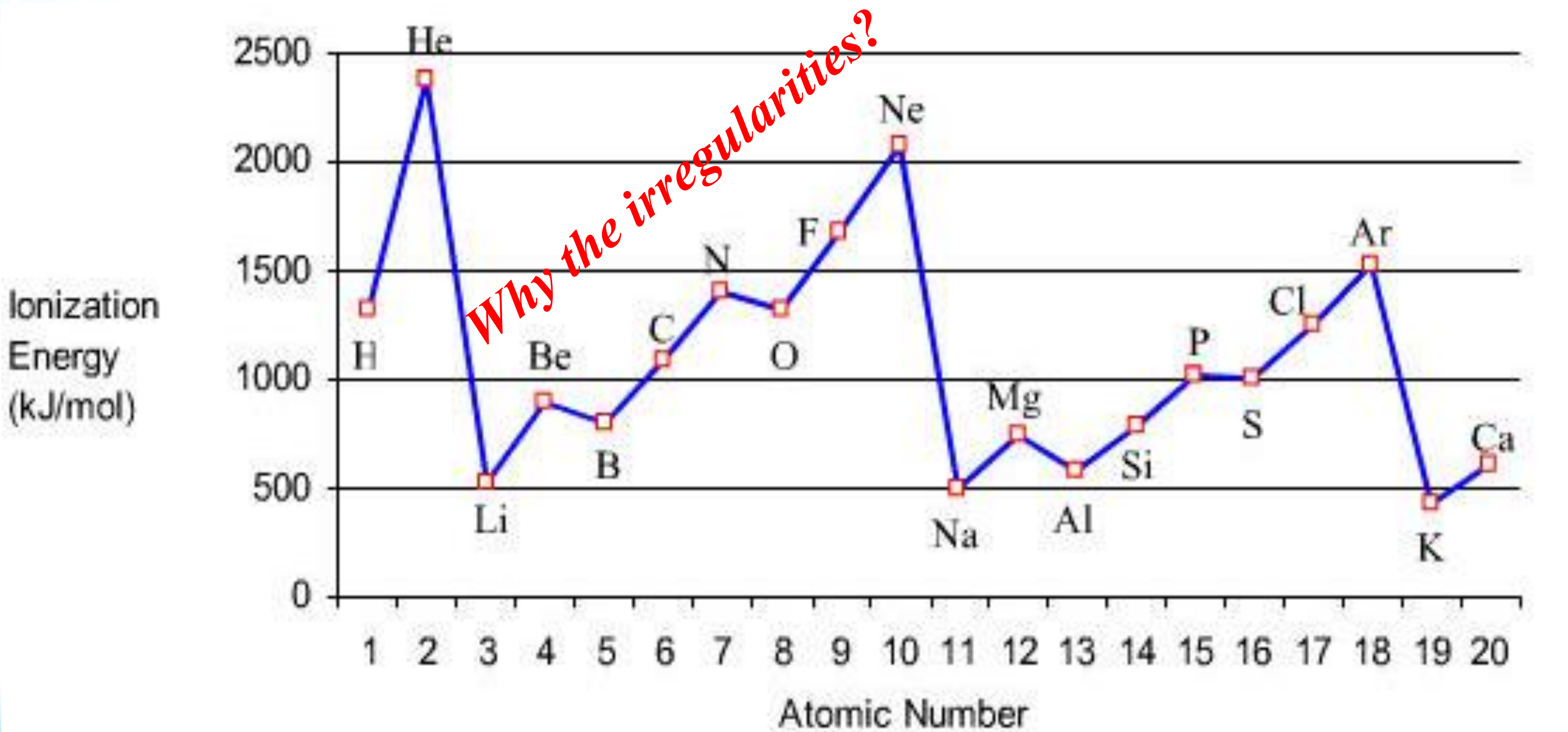
Cs 375.7	Ba 508.1	Tl 595.4	Pb 722.9	Bi 710.6	Po 821	At --	Rn 1047.8
Fr --	Ra 514.6						

TRY IT

Metals tend to lose/gain electrons, meaning it takes less/more energy (lower/higher I.E.)?

Non-metals tend to lose/gain electrons, meaning it would require less/more energy (lower/higher I.E.)?

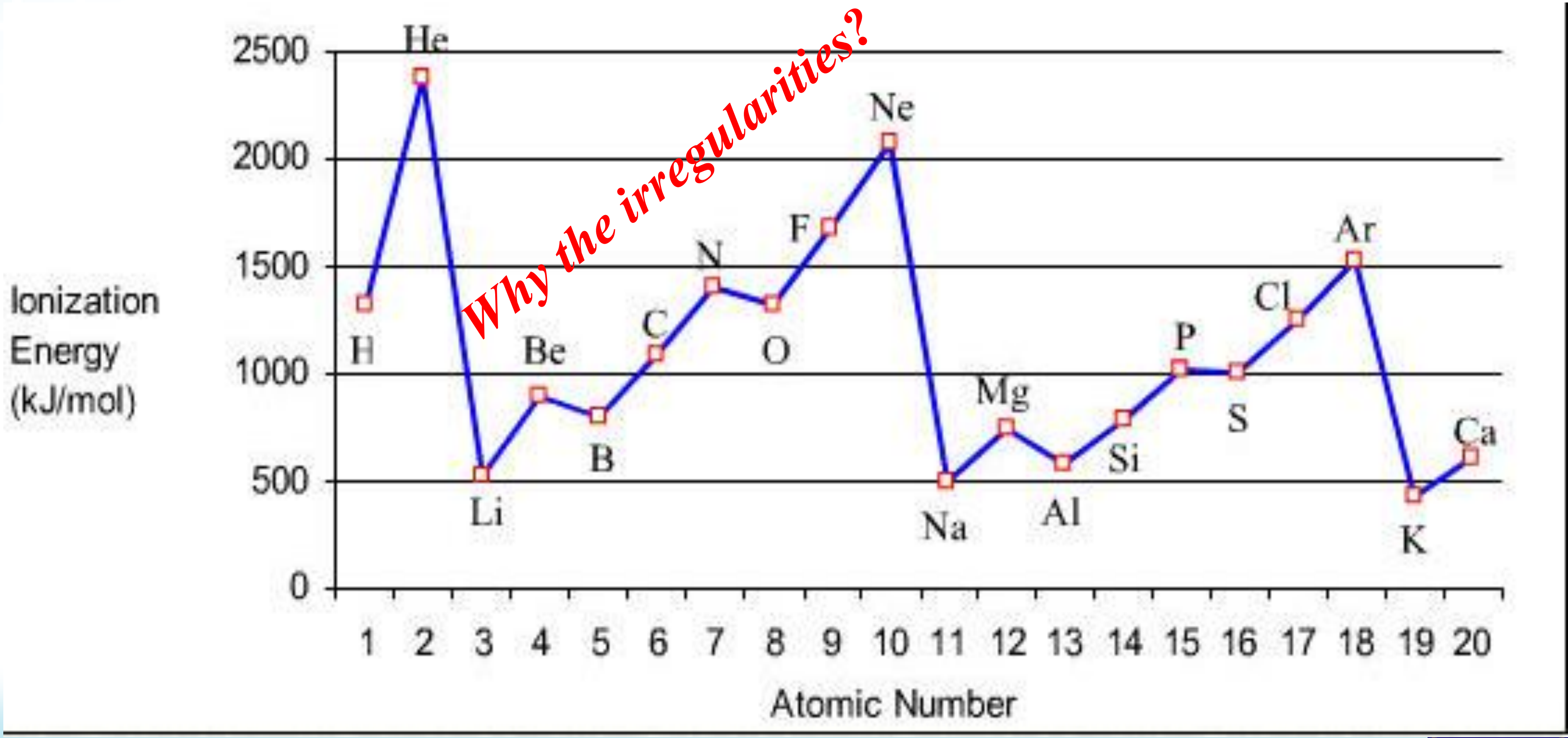


Trends in Ionization Energy

TRY IT

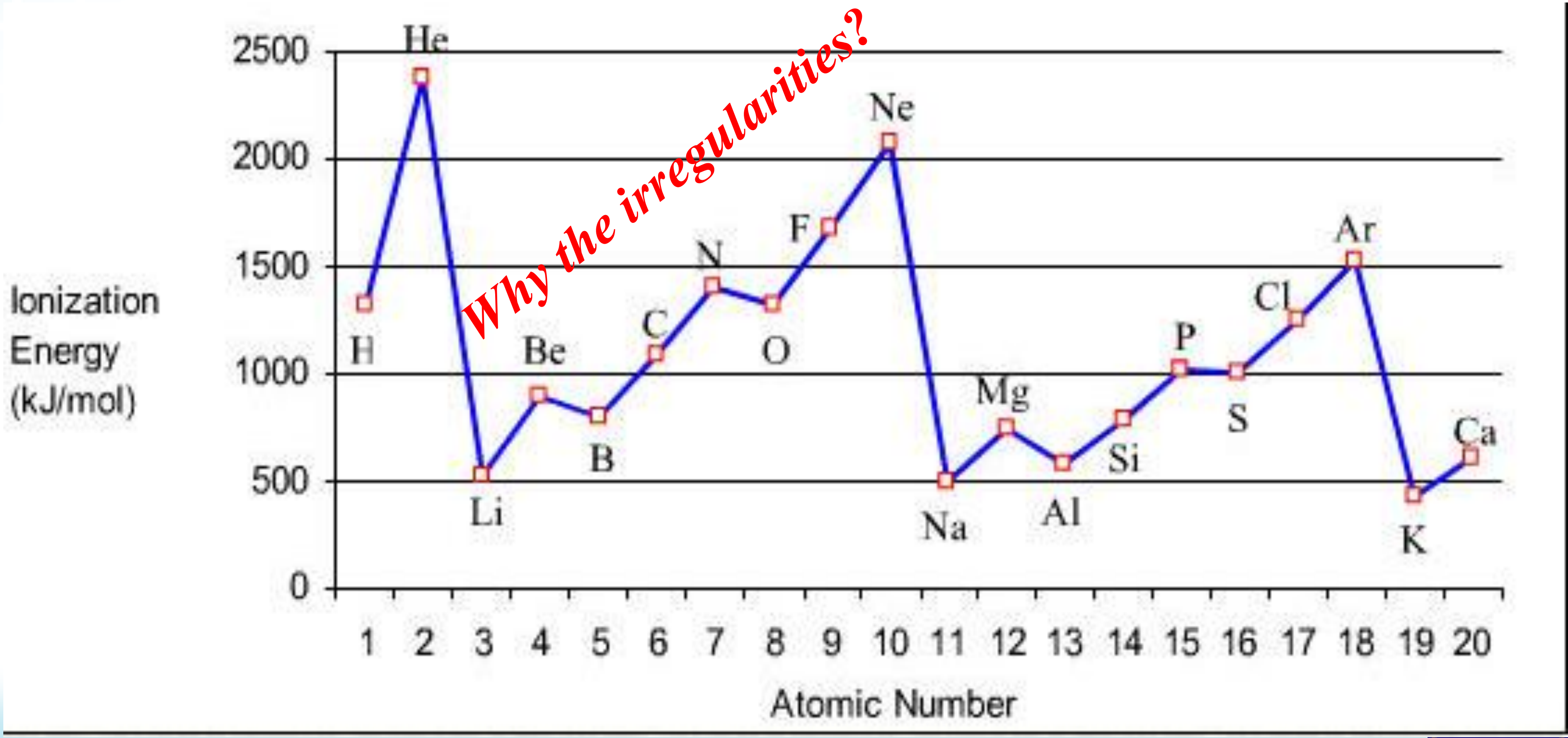
Metals tend to lose electrons, meaning it takes LESS energy (lower I.E.)

Non-metals tend to gain electrons, meaning it would require MORE energy (higher I.E.)



Enrichment

The irregularities are produced when electrons **enter the "p" sublevel** (e.g. Be, Mg) and again when the electrons **fill the first "p" orbital** (Hund's Rule) [e.t. N, P]



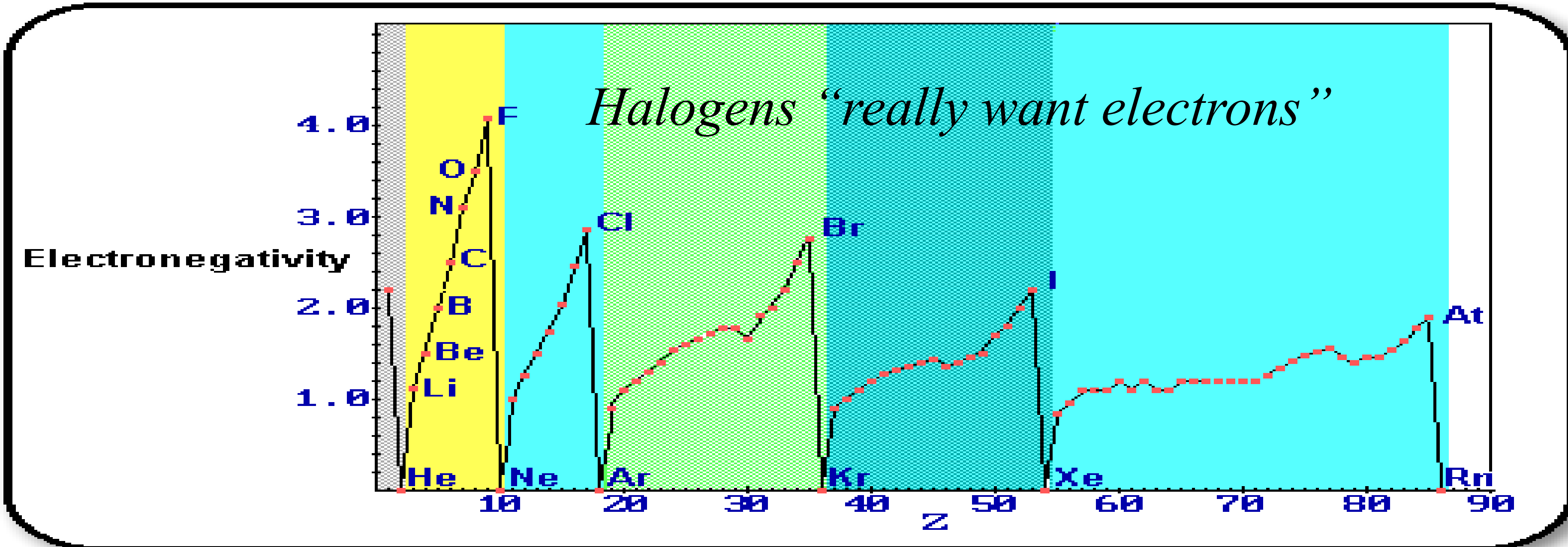
Electronegativity

The measure of the **electron attracting power** (ELECTRON AFFINITY) of an atom when it bonds with another atom (*to gain ideal electron configuration*).

A property used to predict Bonding type during a reaction.

- Increase/decrease along a period or row?
- Increase/decrease down a group or family?

TRY IT



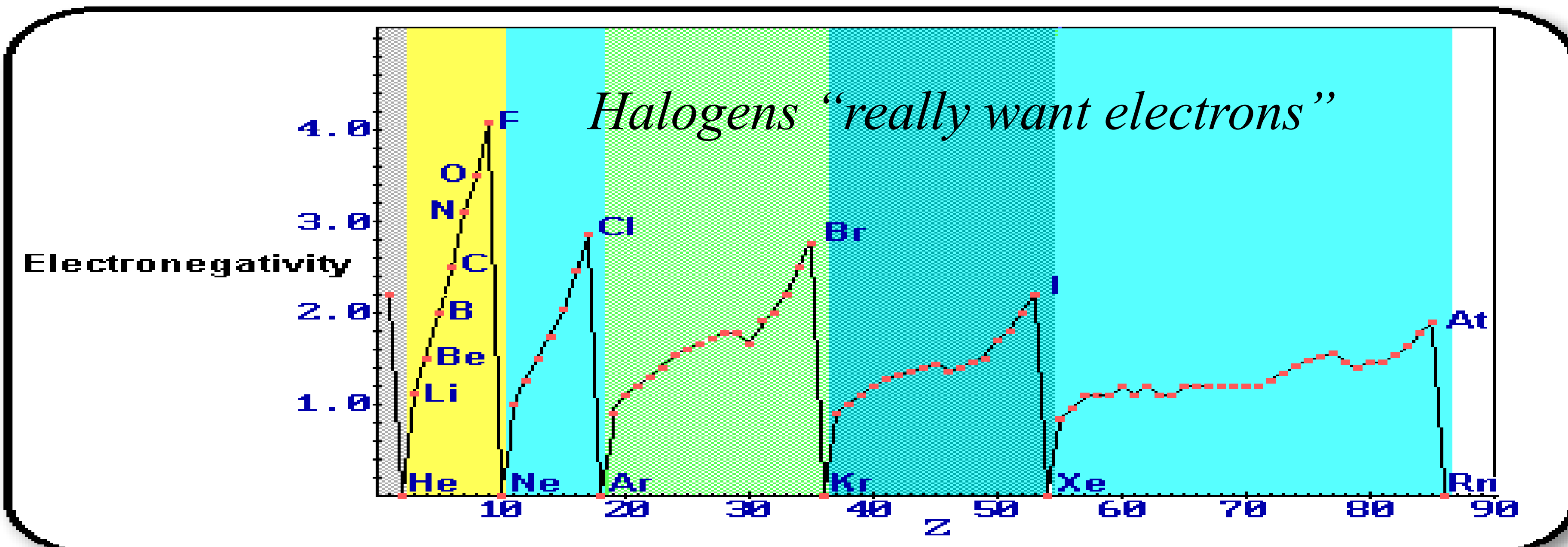
Electronegativity

The measure of the **electron attracting power** (ELECTRON AFFINITY) of an atom when it bonds with another atom (*to gain ideal electron configuration*).

A property used to predict Bonding type during a reaction.

- INCREASES along a period or row.
- DECREASES down a group or family.

TRY IT



Trends in Electronegativity

Describe metals in terms of electrons and electronegativity.

Describe non-metals in terms of electrons and electronegativity.

TRY IT

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		

Trends in Electronegativity

Metals do not "gain" electrons, meaning LESS electronegativity.

Non-metals DO gain electrons, meaning MORE electronegativity.

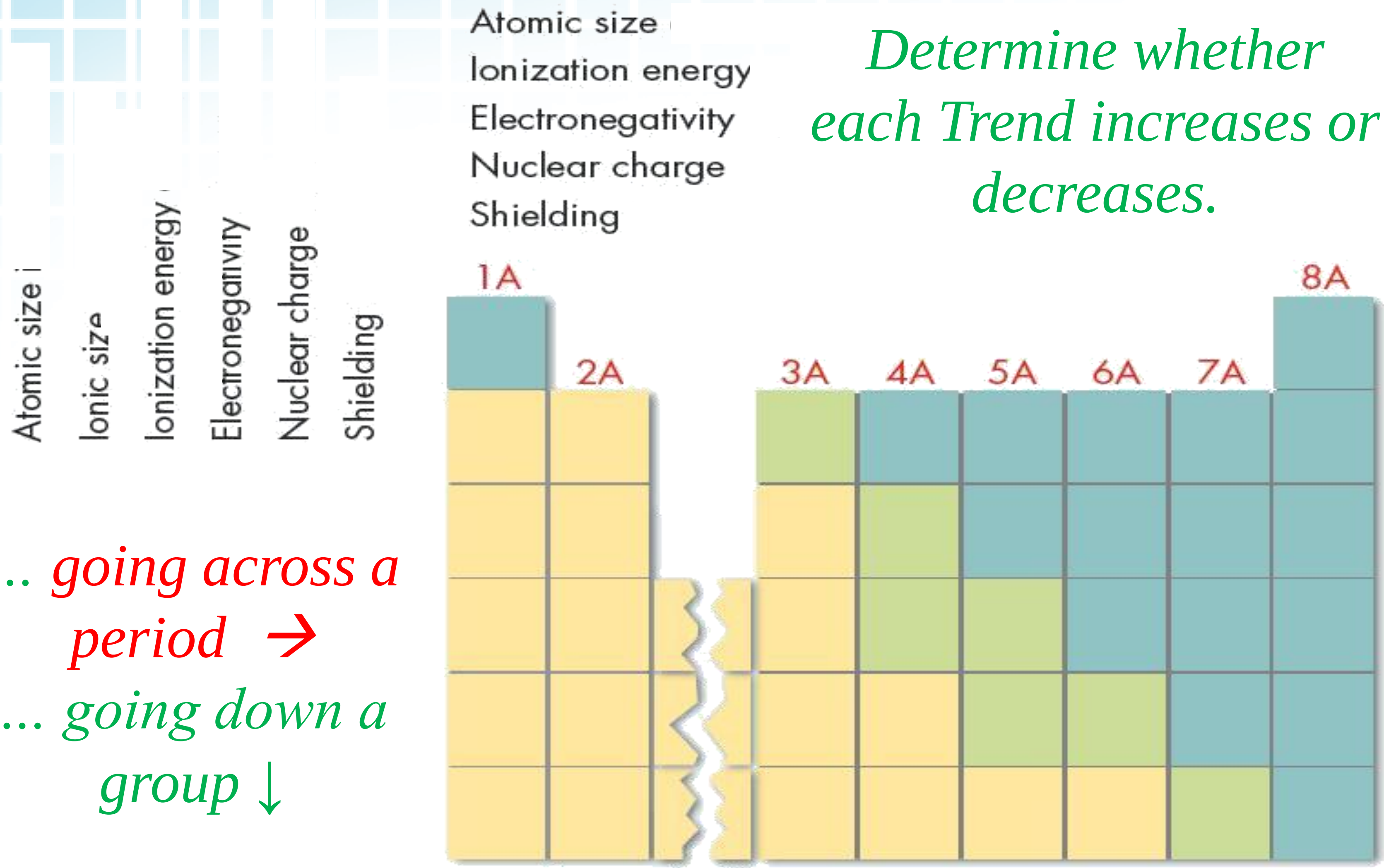
TRY IT

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		

SUMMARY

QUICK CHECK

Determine whether each Trend increases or decreases.



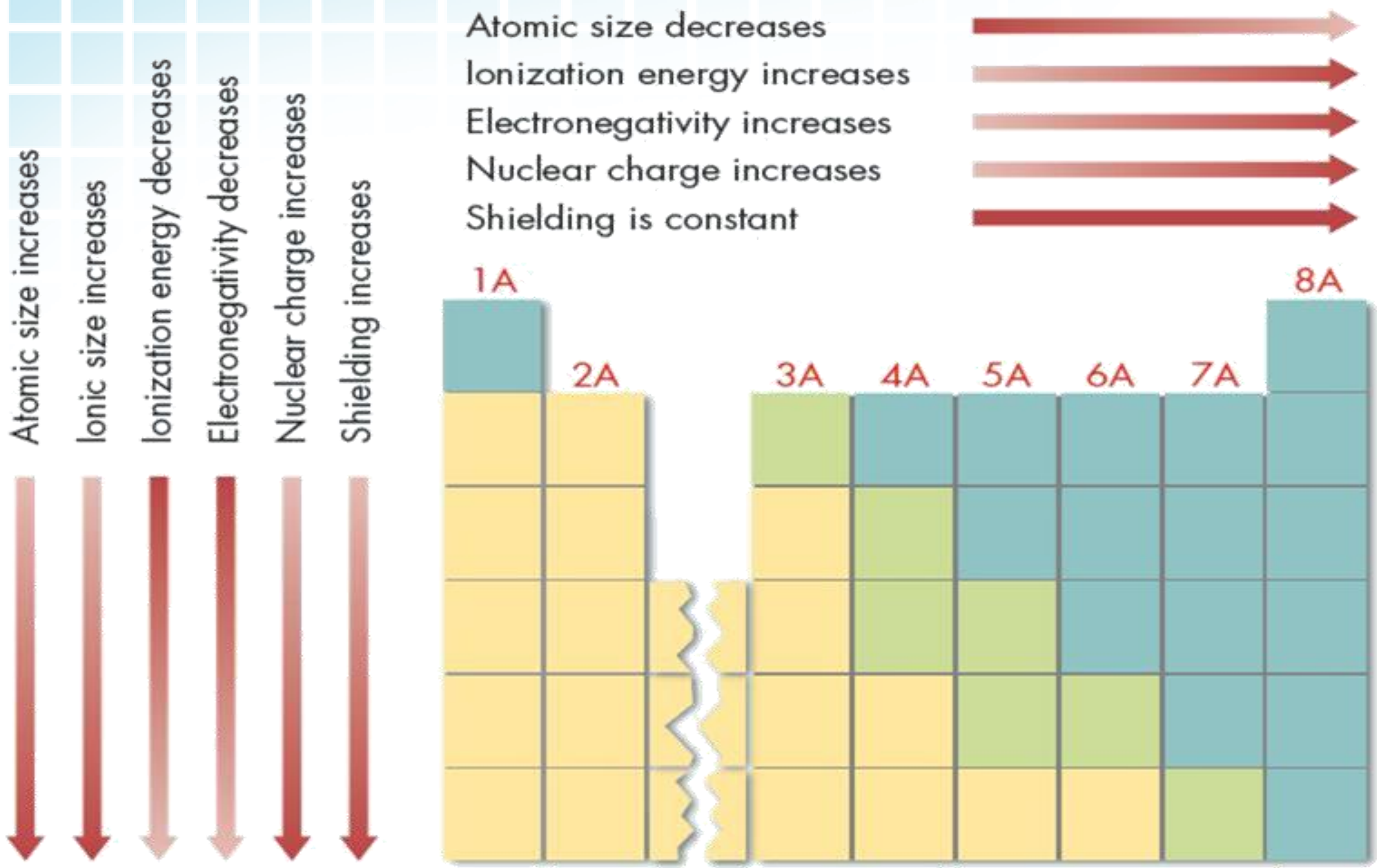
… going across a period →

… going down a group ↓

6.3 Periodic Trends

SUMMARY

QUICK CHECK



The Arrangement of the Periodic Table

LESSON SUMMARY

The periodic table contains a great deal of information on the elements.

- *Periods* refer to horizontal rows of the periodic table.
- *Groups* or *families* refer to vertical columns of the periodic table.
- Cells of the periodic table contain information such as the atomic symbol, atomic number, atomic mass, name of the element, electron configuration, and possible oxidation numbers.
- Elements can be categorized broadly as metals, nonmetals, or semimetals (metalloids).

Classifying the Elements

LESSON SUMMARY

Groups

- Alkali metals: most reactive metals, soft, oxidize quickly.
- Alkaline earth metals: not as reactive as alkali metals, brittle, shiny.
- Transition metals: form colored compounds, good conductors of electricity.
- Halogens: most reactive nonmetals.
- Noble gases: lowest chemical reactivity, used in lighting.
- Inner transition metals: radioactive, used in nuclear power plants.

KEY

Relative atomic masses are based on $^{12}C = 12.00000$

Atomic Mass	Selected Oxidation States	Symbol	Atomic Number	Electron Configuration
12.0111	−4, +2, +4	**C**	6	$1s^2 2s^2 2p^2$

Period	*s*-block 1 IA
1	1.00794 +1 −1 **H** 1 $1s^1$

s-block

GROUP

New Designation

Former Designation (prior to 1984 IUPAC decision)

d-block

Transition Elements

Period	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	
2	6.941 +1 **Li** 3 $1s^2 2s^1$	9.01218 +2 **Be** 4 $1s^2 2s^2$									
3	22.98977 +1 **Na** 11 $[Ne]3s^1$	24.305 +2 **Mg** 12 $[Ne]3s^2$									
4	39.0983 +1 **K** 19 $[Ar]4s^1$	40.08 +2 **Ca** 20 $[Ar]4s^2$	44.9559 +3 **Sc** 21 $[Ar]3d^1 4s^2$	47.88 +2 +3 +4 **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 +2 +3 +4 +5 **V** 23 $[Ar]3d^3 4s^2$	51.996 +2 +3 +6 **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 +2 +3 +4 +7 **Mn** 25 $[Ar]3d^5 4s^2$	55.847 +2 +3 **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 +2 +3 **Co** 27 $[Ar]3d^7 4s^2$	58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.546 29 [Ar]3d
5	85.4678 +1 **Rb** 37 $[Kr]5s^1$	87.62 +2 **Sr** 38 $[Kr]5s^2$	88.9059 +3 **Y** 39 $[Kr]4d^1 5s^2$	91.224 +4 **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 +3 +5 **Nb** 41 $[Kr]4d^4 5s^1$	95.94 +3 +6 **Mo** 42 $[Kr]4d^5 5s^1$	(98) +4 +6 +7 **Tc** 43 $[Kr]4d^6 5s^1$	101.07 +3 **Ru** 44 $[Kr]4d^7 5s^1$	102.906 +3 **Rh** 45 $[Kr]4d^8 5s^1$	106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.86 47 [Kr]4d
6	132.905 +1 **Cs** 55 $[Xe]6s^1$	137.33 +2 **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 +4 **Hf** 72 $[Xe]4f^{14}5d^2 6s^2$	180.948 +5 **Ta** 73 $[Xe]4f^{14}5d^3 6s^2$	183.85 +6 **W** 74 $[Xe]4f^{14}5d^4 6s^2$	186.207 +4 +6 +7 **Re** 75 $[Xe]4f^{14}5d^5 6s^2$	190.2 +3 +4 **Os** 76 $[Xe]4f^{14}5d^6 6s^2$	192.22 +3 +4 **Ir** 77 $[Xe]4f^{14}5d^7 6s^2$	195.08 +2 +4 **Pt** 78 $[Xe]4f^{14}5d^9 6s^1$	196.96 79 [Xe]4f
7	(223) +1 **Fr** 87 $[Rn]7s^1$	226.025 +2 **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		

* The sys
103 wil

nasses are
2.00000

lation States

s-block
18
O

He
4.00260 (0)
He 2
$1s^2$

p-block

GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 O
			10.81 (+3) **B** 5 $1s^2 2s^2 2p^1$	12.0111 (−4, +2, +4) **C** 6 $1s^2 2s^2 2p^2$	14.0067 (−3, −2, −1, +1, +2, +3, +4, +5) **N** 7 $1s^2 2s^2 2p^3$	15.9994 (−2) **O** 8 $1s^2 2s^2 2p^4$	18.998403 (−1) **F** 9 $1s^2 2s^2 2p^5$	20.179 (0) **Ne** 10 $1s^2 2s^2 2p^6$
			26.98154 (+3) **Al** 13 $[Ne]3s^2 3p^1$	28.0855 (−4, +2, +4) **Si** 14 $[Ne]3s^2 3p^2$	30.97376 (−3, +3, +5) **P** 15 $[Ne]3s^2 3p^3$	32.06 (−2, +4, +6) **S** 16 $[Ne]3s^2 3p^4$	35.453 (−1, +1, +3, +5, +7) **Cl** 17 $[Ne]3s^2 3p^5$	39.948 (0) **Ar** 18 $[Ne]3s^2 3p^6$
58.69 (+2, +3) **Ni** 28 $[Ar]3d^8 4s^2$	63.546 (+1, +2) **Cu** 29 $[Ar]3d^{10} 4s^1$	65.39 (+2) **Zn** 30 $[Ar]3d^{10} 4s^2$	69.72 (+3) **Ga** 31 $[Ar]3d^{10} 4s^2 4p^1$	72.59 (−4, +2, +4) **Ge** 32 $[Ar]3d^{10} 4s^2 4p^2$	74.9216 (−3, +3, +5) **As** 33 $[Ar]3d^{10} 4s^2 4p^3$	78.96 (−2, +4, +6) **Se** 34 $[Ar]3d^{10} 4s^2 4p^4$	79.904 (−1, +1, +5) **Br** 35 $[Ar]3d^{10} 4s^2 4p^5$	83.80 (0, +2) **Kr** 36 $[Ar]3d^{10} 4s^2 4p^6$
106.42 (+2, +4) **Pd** 46 $[Kr]4d^{10} 5s^0$	107.868 (+1) **Ag** 47 $[Kr]4d^{10} 5s^1$	112.41 (+2) **Cd** 48 $[Kr]4d^{10} 5s^2$	114.82 (+3) **In** 49 $[Kr]4d^{10} 5s^2 5p^1$	118.71 (+2, +4) **Sn** 50 $[Kr]4d^{10} 5s^2 5p^2$	121.75 (−3, +3, +5) **Sb** 51 $[Kr]4d^{10} 5s^2 5p^3$	127.60 (−2, +4, +6) **Te** 52 $[Kr]4d^{10} 5s^2 5p^4$	126.905 (−1, +1, +5, +7) **I** 53 $[Kr]4d^{10} 5s^2 5p^5$	131.29 (0, +2, +4, +6) **Xe** 54 $[Kr]4d^{10} 5s^2 5p^6$
195.08 (+2, +4) **Pt** 78 $[Xe]4f^{14} 5d^9 6s^1$	196.967 (+1, +3) **Au** 79 $[Xe]4f^{14} 5d^{10} 6s^1$	200.59 (+1, +2) **Hg** 80 $[Xe]4f^{14} 5d^{10} 6s^2$	204.383 (+1, +3) **Tl** 81 $[Xe]4f^{14} 5d^{10} 6s^2 6p^1$	207.2 (+2, +4) **Pb** 82 $[Xe]4f^{14} 5d^{10} 6s^2 6p^2$	208.980 (+3, +5) **Bi** 83 $[Xe]4f^{14} 5d^{10} 6s^2 6p^3$	(209) (+2, +4) **Po** 84 $[Xe]4f^{14} 5d^{10} 6s^2 6p^4$	(210) **At** 85 $[Xe]4f^{14} 5d^{10} 6s^2 6p^5$	(222) (0) **Rn** 86 $[Xe]4f^{14} 5d^{10} 6s^2 6p^6$

IONIZATION ENERGIES AND ELECTRONEGATIVITIES

H: 313 ← First Ionization Energy (kcal/mol of atoms)
H: 2.2 ← Electronegativity*

1	2	13	14	15	16	17	18
H 313 2.2							He 567
Li 125 1.0	Be 215 1.5	B 191 2.0	C 260 2.6	N 336 3.1	O 314 3.5	F 402 4.0	Ne 497
Na 119 0.9	Mg 176 1.2	Al 138 1.5	Si 188 1.9	P 242 2.2	S 239 2.6	Cl 300 3.2	Ar 363
K 100 0.8	Ca 141 1.0	Ga 138 1.6	Ge 182 1.9	As 226 2.0	Se 225 2.5	Br 273 2.9	Kr 323
Rb 96 0.8	Sr 131 1.0	In 133 1.7	Sn 169 1.8	Sb 199 2.1	Te 208 2.3	I 241 2.7	Xe 280
Cs 90 0.7	Ba 120 0.9	Tl 141 1.8	Pb 171 1.8	Bi 168 1.9	Po 194 2.0	At 2.2	Rn 248
Fr 0.7	Ra 122 0.9						

* Arbitrary scale based on fluorine = 4.0

Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2{}^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium
$(NH_4)^{+1}$