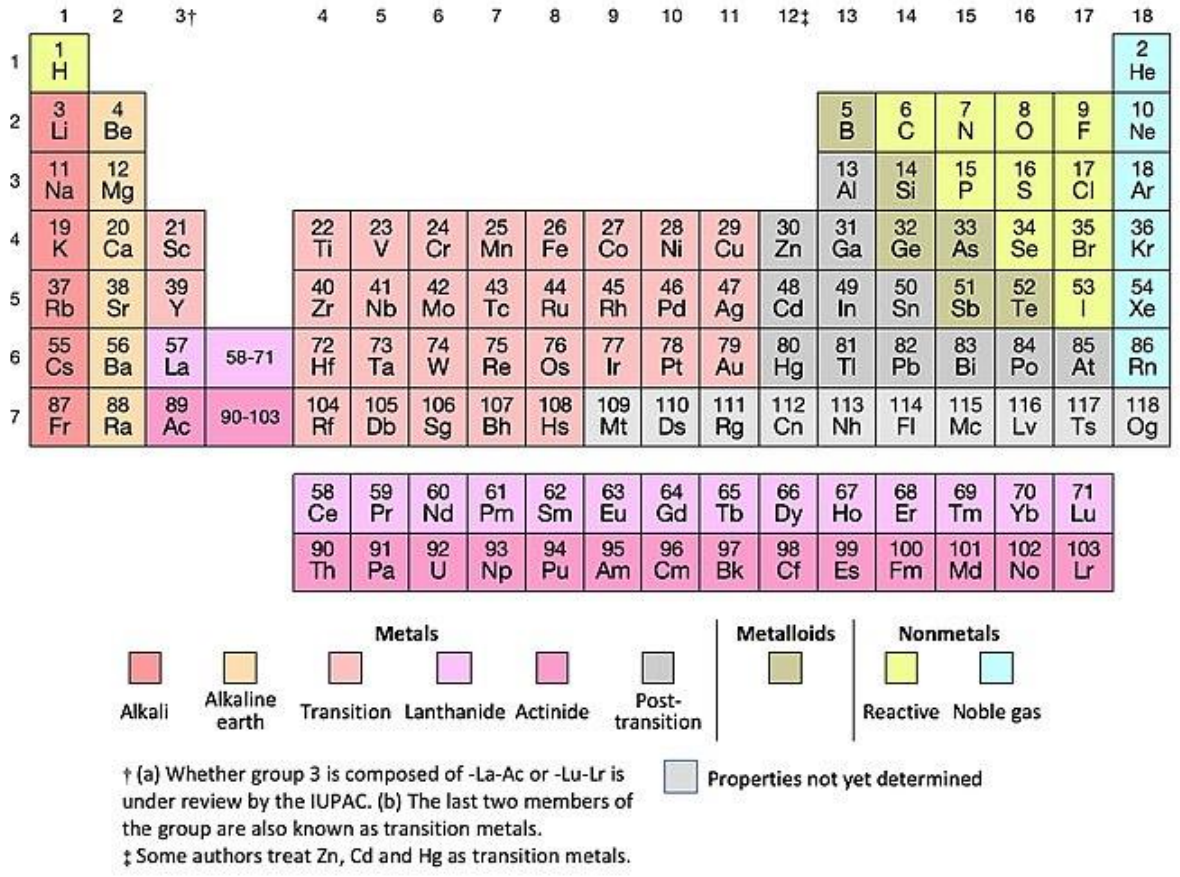
Periodic Table: Classification and Periodic Properties of Elements

What is the Periodic Table

- The periodic table, also known as the periodic table of elements, is a tabular display of the chemical elements, which are arranged by atomic number, electron configuration, and recurring chemical properties. The structure of the table shows periodic trends of the elements.



How the Periodic Table was developed – historical background

- In 1789, Antoine Lavoisier published a list of 33 chemical elements, grouping them into gases, metals, nonmetals, and earths.

- During 1817 - 1829, Johann Wolfgang Döbereiner observed that many of the elements could be grouped into triads based on their chemical properties.

- He also observed that, when arranged by atomic weight, the second member of each triad was roughly the average of the first and the third. This became known as the Law of Triads.

Element	Atomic weight	Element	Atomic weight	Element	Atomic weight
Li	7	Ca	40	Cl	35.5
Na	23	Sr	88	Br	80
K	39	Ba	137	I	127

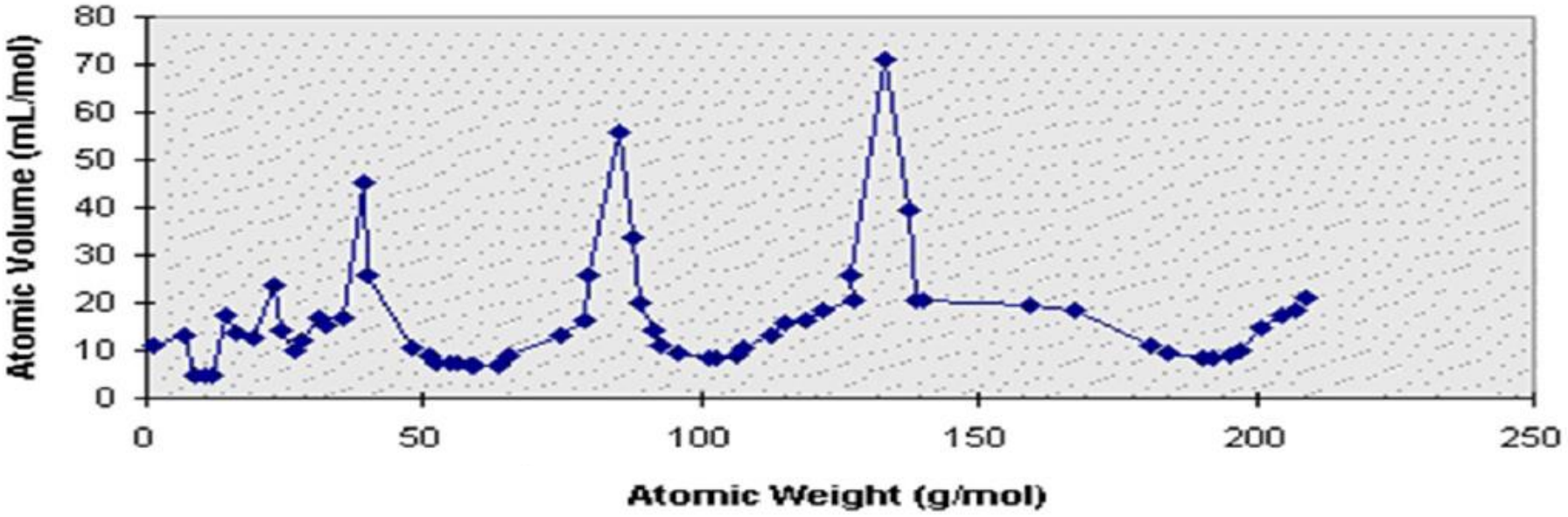
Berzelius (1828) also published his table of atomic masses containing 54 elements. Most of his values conform with those in the modern periodic table.

John Newlands (1864) arranged the elements in an order of increasing atomic masses. He arranged elements in groups with seven members each, similar to the octave of the musical scale. This is referred to as *Newlands' Law of Octaves*.

Table 5.3 Newlands' Octaves

sa (do)	re (re)	ga (mi)	ma (fa)	pa (so)	da (la)	ni (ti)
H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe
Co and Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce and La	Zr	—	—

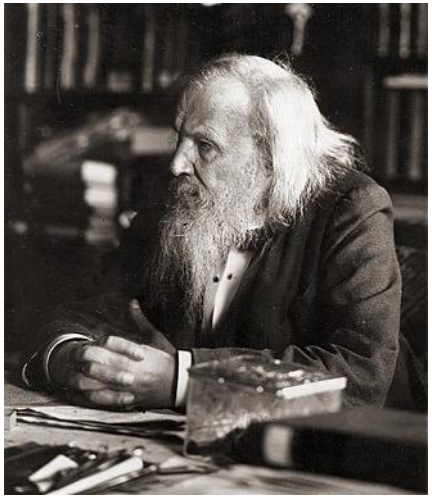
Julius Lothar Meyer (during 1864 - 1868) maintained that the properties of elements were functions of their atomic weights. He prepared a graph wherein he plotted the atomic volume of the elements (horizontally) *versus* its atomic weights (vertically)



- the graph consists of a series of maximums and minimums - the most electropositive elements would appear at the peaks in the order of their atomic weights. - **Periodicity**

Dmitri Mendeleev (1869) created the first well accepted version of the periodic table.

- He arranged the elements in order of increasing atomic weights providing intervals on periods which were not always of the same length.
- Blank spaces were left open to add the new elements (yet to be discovered).
- In 1870, he first tried to characterize the yet undiscovered elements, and he gave detailed predictions for three elements, which he termed ***eka-boron (Scandium)*, *eka-aluminium (Gallium)*, and *eka-silicium (Germanium)***

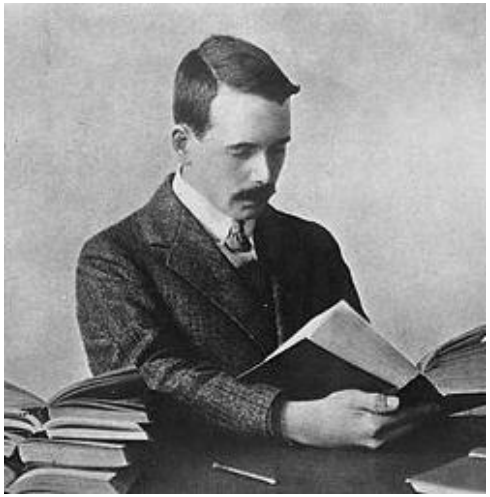


Property	Mendeleev's Predictions for Eka-Silicon (made in 1871)	Observed Properties of Germanium (discovered in 1886)
Atomic weight	72	72.59
Density (g/cm^3)	5.5	5.35
Specific heat (J/g-k)	0.305	0.309
Melting point (°C)	High	947
Color	Dark gray	Grayish white
Formula of oxide	XO_2	GeO_2
Density of oxide (g/cm^3)	4.7	4.70
Formula of chloride	XCl_4	$GeCl_4$
Boiling point of chloride (°C)	A little under 100	84

Further Development

In the early periodic tables, elements were arranged according to increasing atomic weights. This misplaced several elements, such as, Argon (A = 40) and Potassium (A = 39); Cobalt (A = 58.9) and Nickel (A = 58.7); Tellurium (A = 128) and Iodine (A = 127).

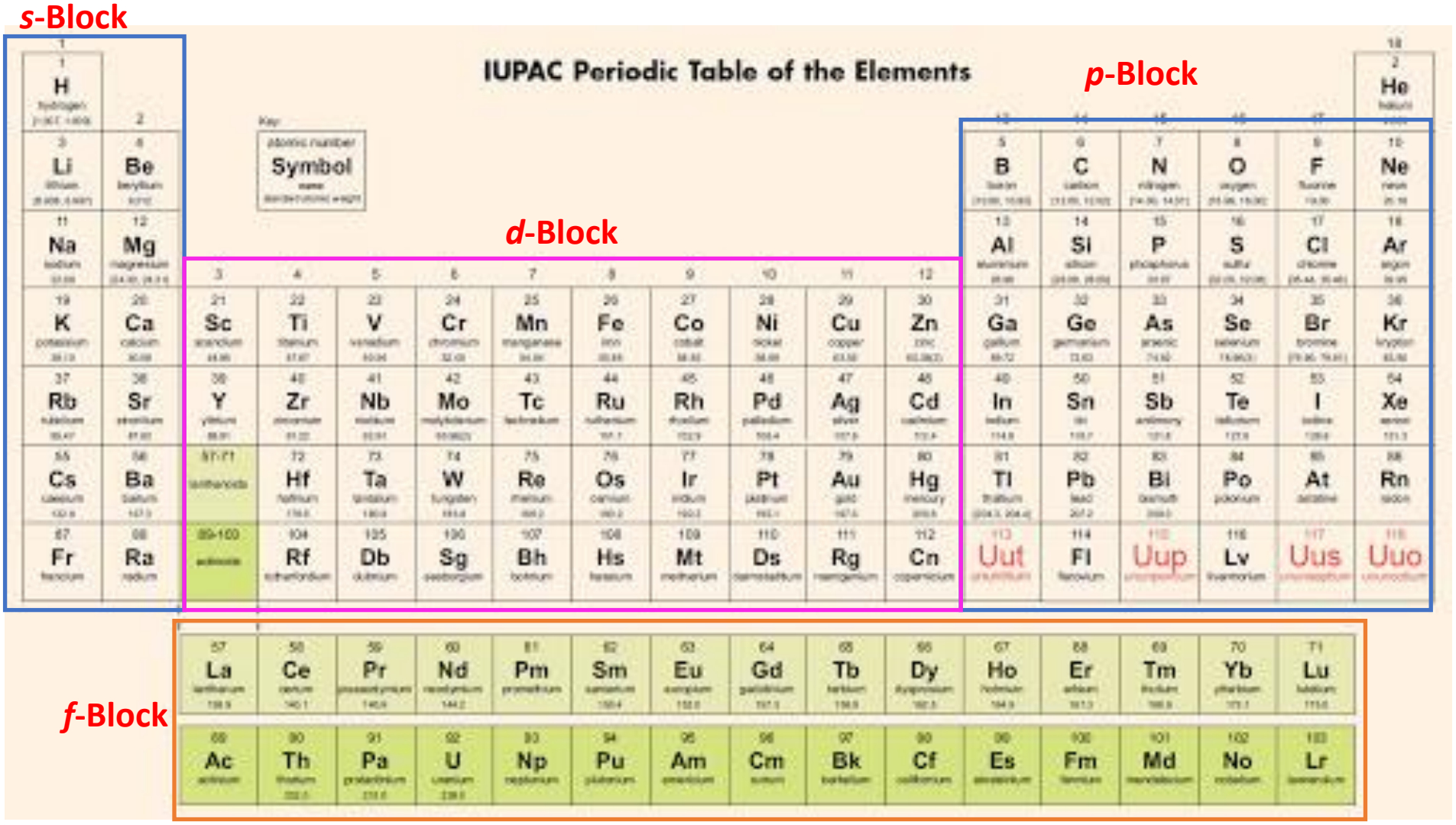
Henry Moseley (1911) suggested that it was the charge of the nucleus and NOT the atomic weight that accounted for the periodic trends in the properties of the elements. Nuclear charge is identical to proton count and determines the value of the **atomic number (*Z*).**



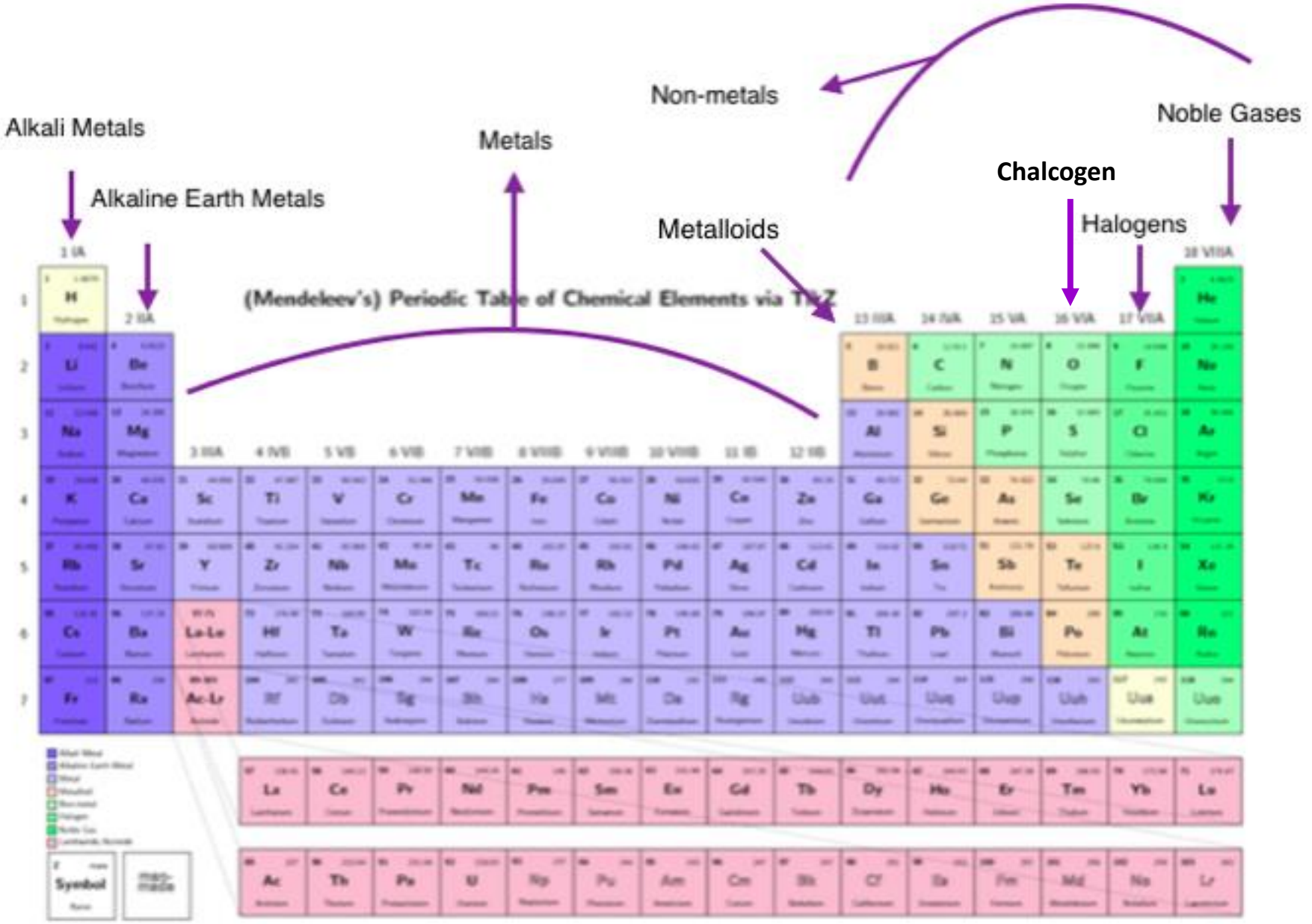
- Thus the position of elements in the periodic table should be arranged by increasing atomic numbers. This concept gave rise to the modern periodic table.

- **Glenn T. Seaborg (1945)** suggested a new periodic table showing the actinides as belonging to a second f-block series.

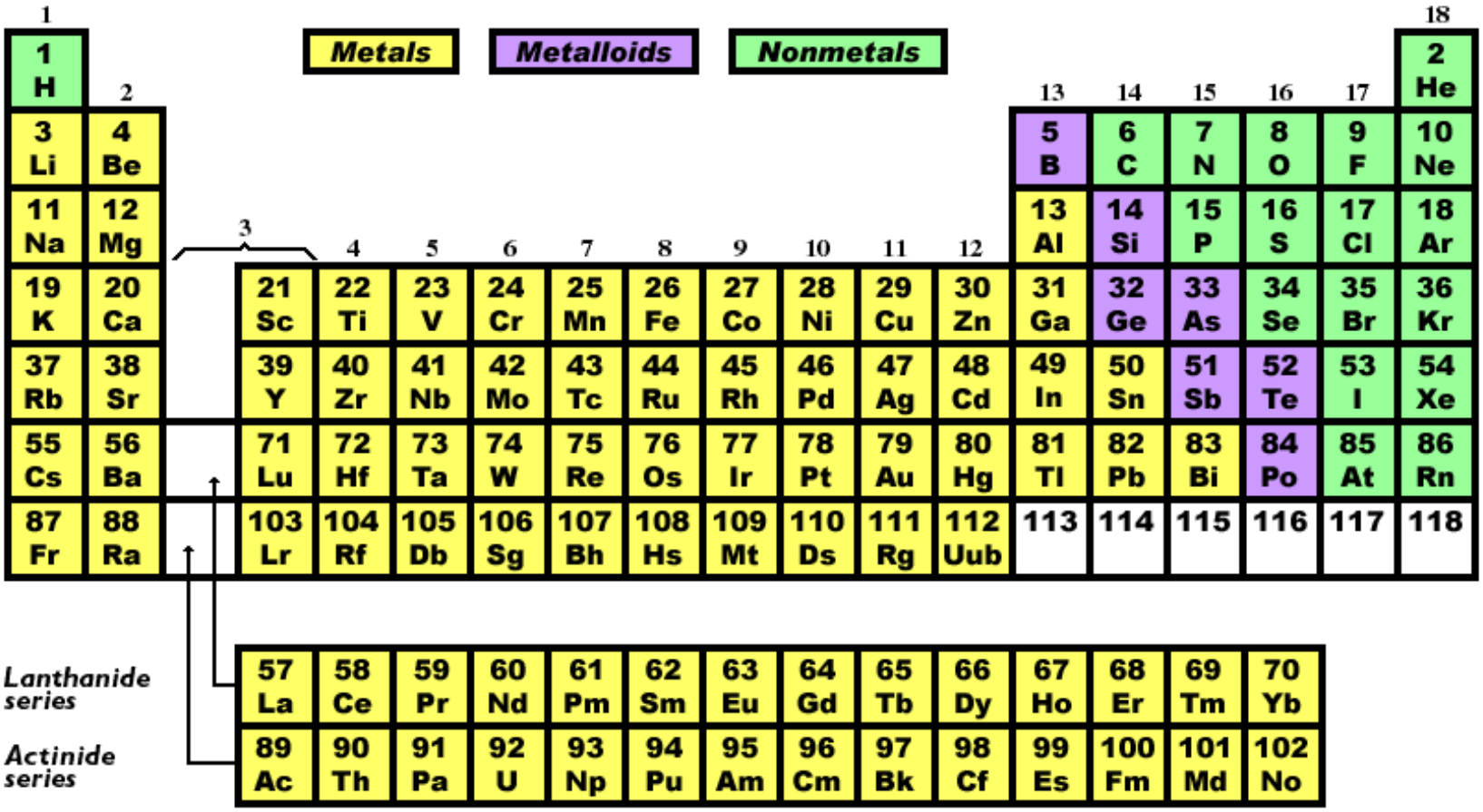
The Modern Periodic Table



Rows = Periods and Column = Groups


Alkali Metals
Alkaline Earth Metals
Metals
Non-metals
Noble Gases
Chalcogen
Halogens
Metalloids
(Mendeleev's) Periodic Table of Chemical Elements via TEZ

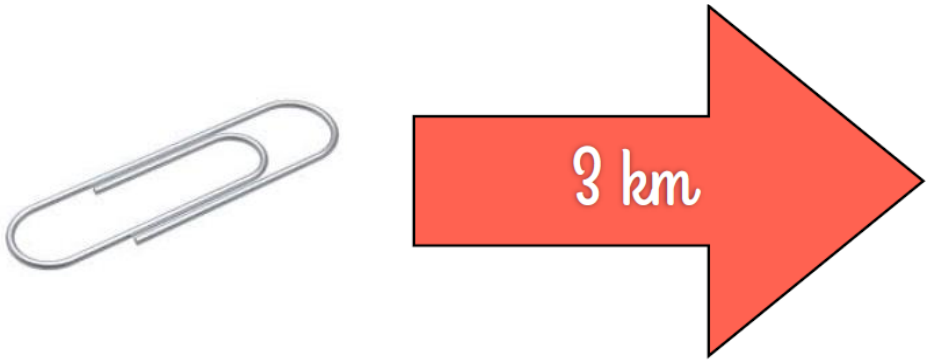
Classification of Elements – Metals, Non-metals and Metalloids



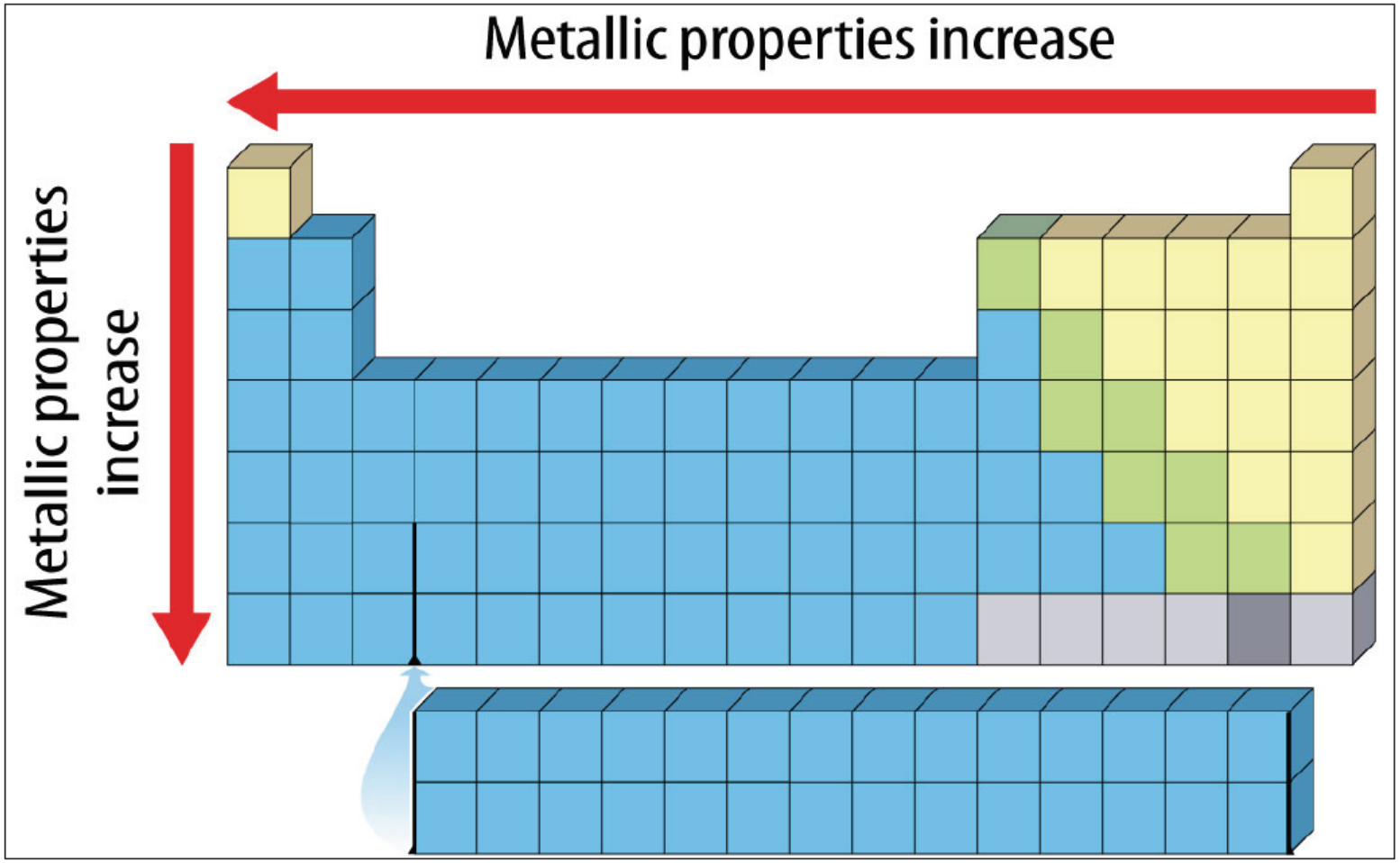
- Almost 3/4 of the elements on the periodic table are metals.
- Metals are on the left side and in the middle of the periodic table.

Metals : Physical Properties

- Lustrous - describes the ability of a metal to reflect light.
- Good conductor of heat and electricity
- Ductility - the ability to be pulled into thin wires.
- A piece of gold with the mass of a paper clip can be pulled into a wire that is more than 3 km long!
- Malleability - the ability of a substance to be hammered or rolled into sheets. An ounce of pure gold the size of a matchbox can be flattened into a sheet the size of a tennis court.
- Density, strength, boiling point, and melting point of a metal are greater than those of other elements.
- Except for mercury, all metals are solid at room temperature



Trends in metallic properties



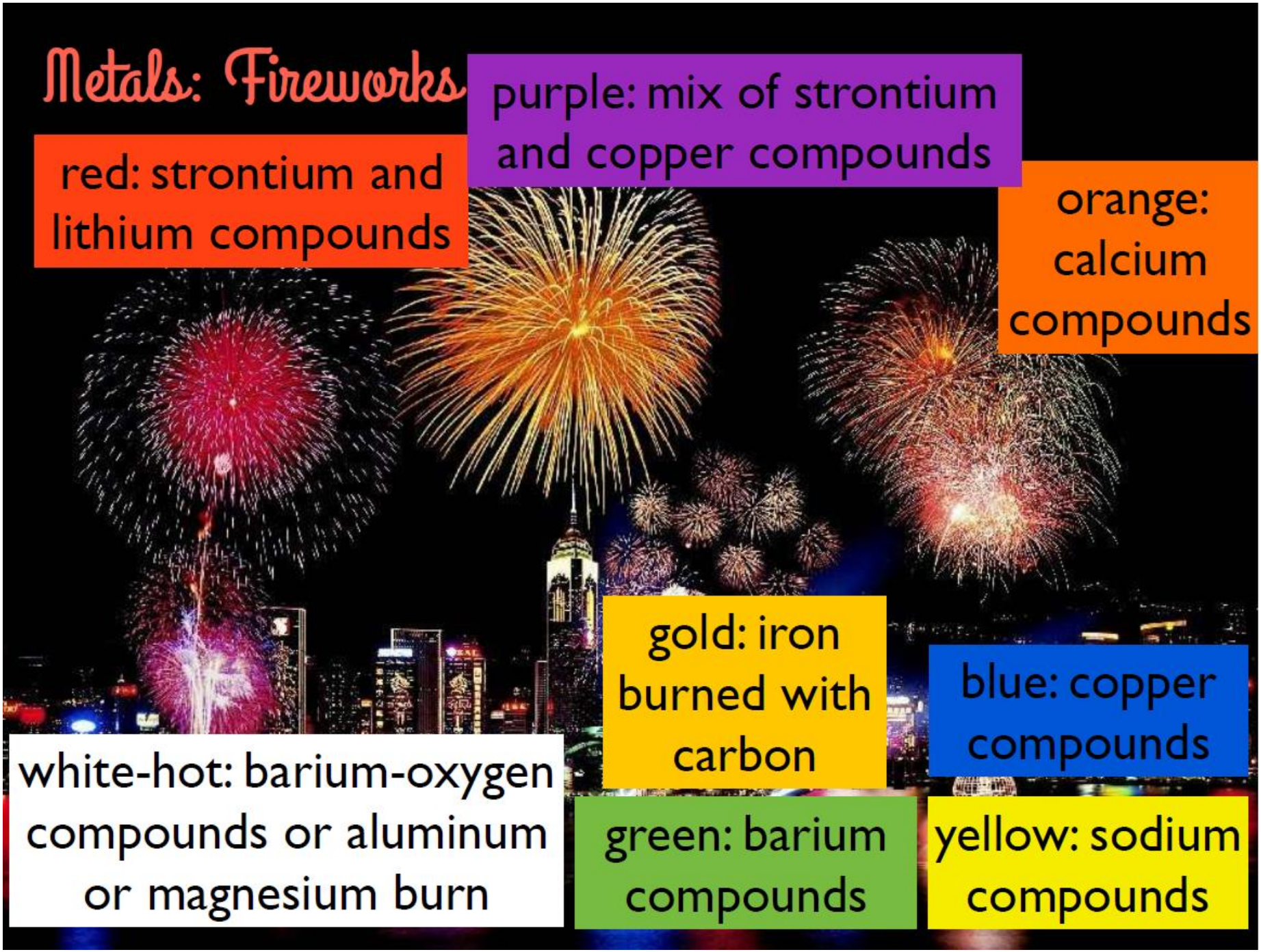
Classification of Metals

- **Alkali metals** consists of lithium (Li), sodium (Na), potassium (K), rubidium (Rb), Cesium (Cs) and francium (Fr) Together with hydrogen, they occupy in Group 1.
- Alkali metals react violently with water.
- **Alkaline earth metals** are six chemical elements in group 2 of the periodic table. They are beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba) and radium (Ra).

- **Transition metals** - The IUPAC definition defines a transition metal as "an element whose atom has a partially filled *d* sub-shell, or which can give rise to cations with an incomplete *d* sub-shell".
- Many scientists describe a "transition metal" as any element in the d-block of the periodic table, which includes groups 3 to 12 on the periodic table.
- n actual practice, the f-block **lanthanide (4-*f*)** and **actinide (5-*f*)** series are also considered transition metals and are called "**inner transition metals**".

- Most of the actinides are radioactive. Pm is the only lanthanide which is radioactive.

Metals: Fireworks



red: strontium and lithium compounds

purple: mix of strontium and copper compounds

orange: calcium compounds

gold: iron burned with carbon

blue: copper compounds

white-hot: barium-oxygen compounds or aluminum or magnesium burn

green: barium compounds

yellow: sodium compounds

Non- Metals: Physical Properties

- Non-metals are poor conductors of heat and electricity.
- Good insulator
- Non-metals are not ductile or malleable.
- Solid non-metals are brittle and break easily.
- They are dull.
- Many non-metals are gases.

Sulfur

Metalloids: Physical Properties

- A metalloid (means metal-like) has physical and chemical properties of both metals and nonmetals.
- They are ductile and malleable.
- Neither good conductor, nor insulator - they act as semiconductor.
- Useful in electronic devices such as computers, tv's and solar cells
- Silicon is the most abundant metalloid in the universe.

Silicon

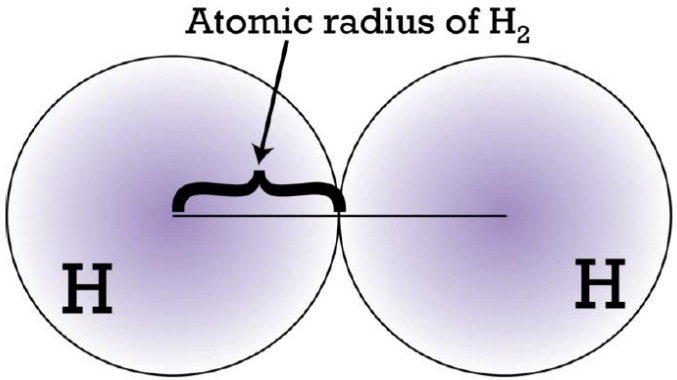
Trends in the Periodic Table

- **Periodic trends are specific patterns that are present in the periodic table that illustrate different aspects of a certain element, including its size and its electronic properties.**

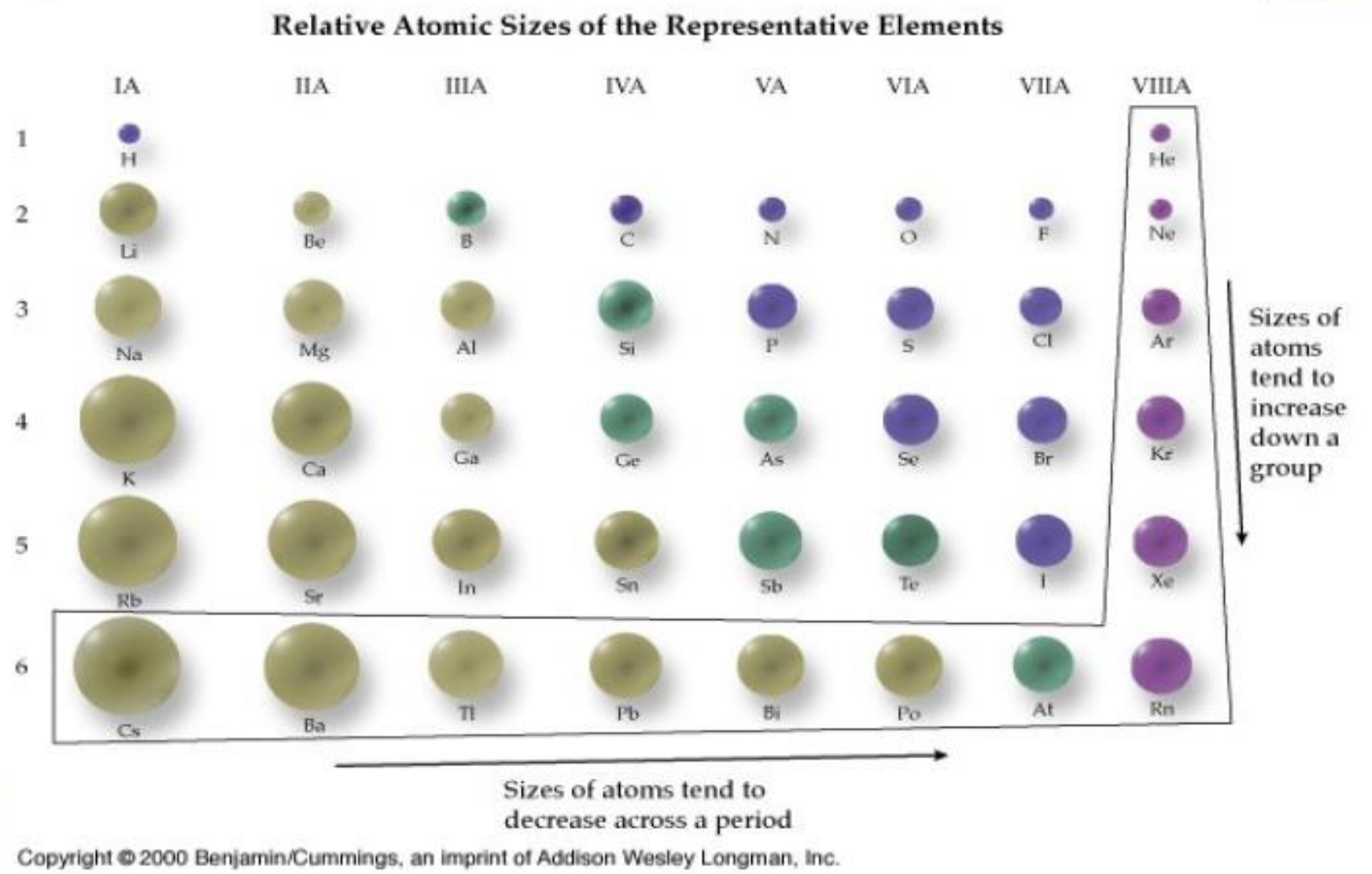
1. **Atomic Radius**
2. **Ionization Energy**
3. **Electron Affinity**
4. **Electronegativity**

1. Atomic Radius

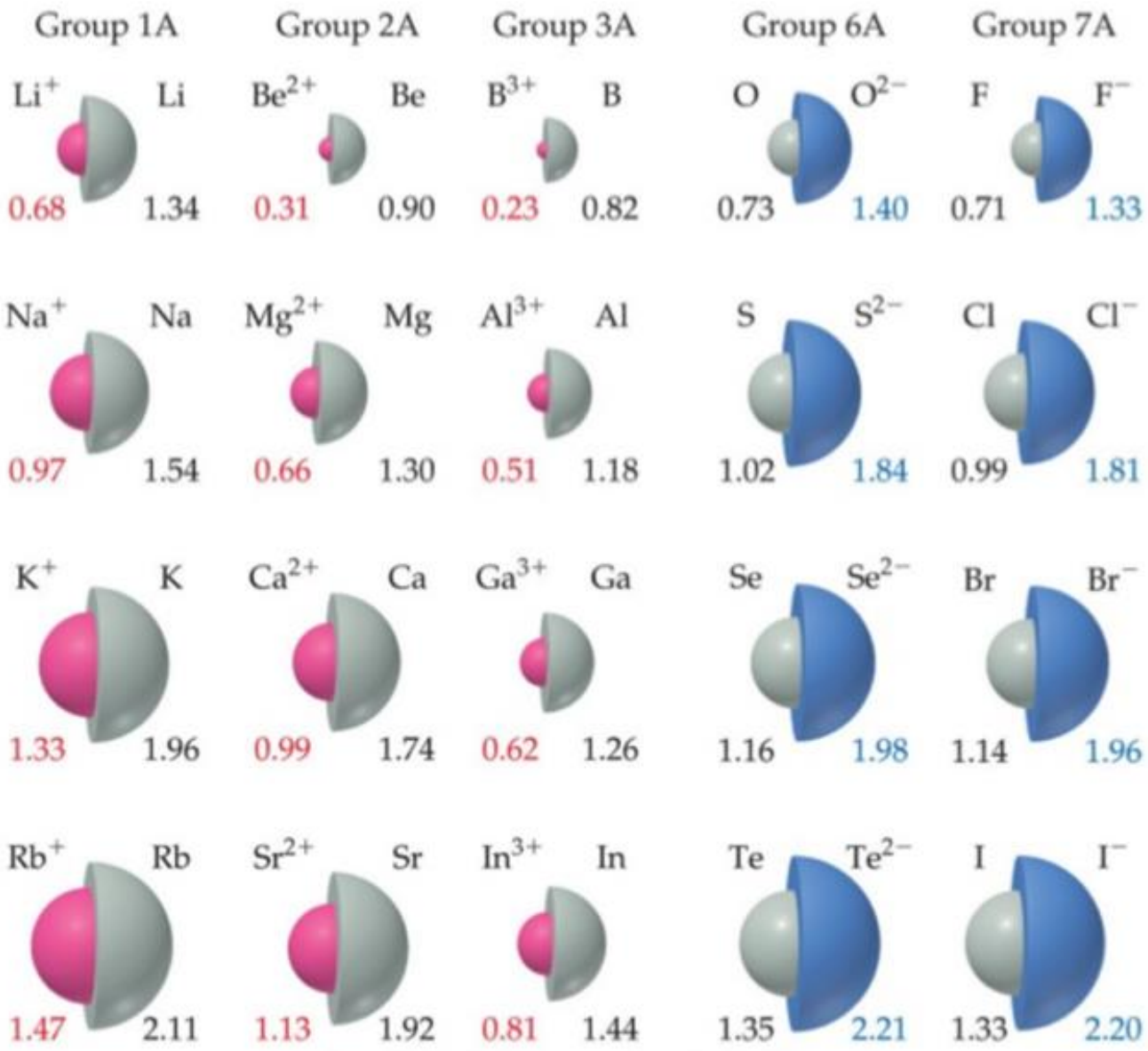
- Size of an atom or volume of an atom is usually expressed as an atomic radius measured in picometers.
- Atomic radius is equal to half the distance between the nuclei of two atoms of the same element when they are joined.



- Atomic size increases as you move down a group. Going down a row adds another energy level of electrons.
- Atomic sizes decreases as you move from left to right across a period. Moving from left to right there is an increase in protons causing greater attraction to electrons.



Size of the Ions *versus* Respective Atoms



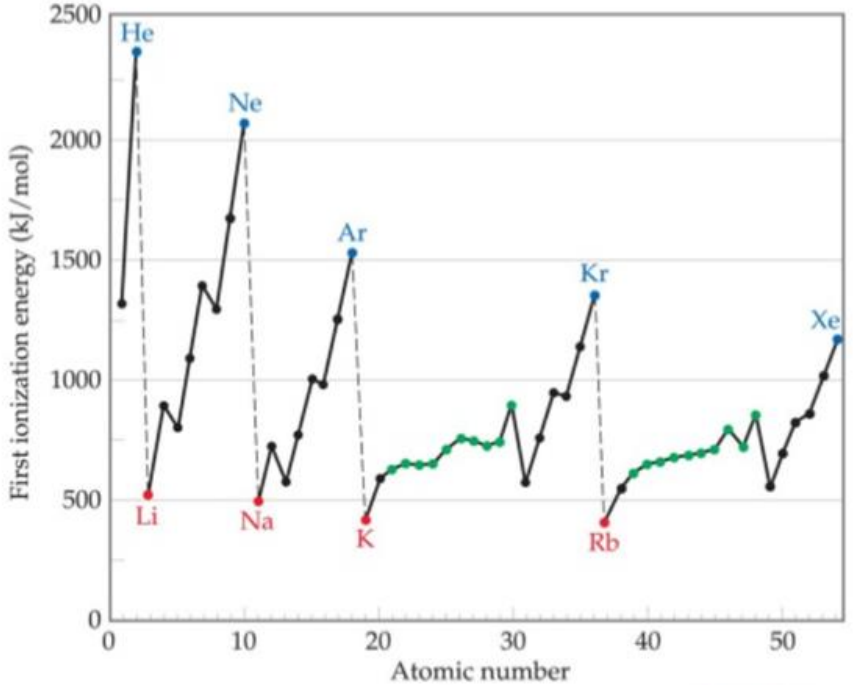
Cations are smaller than atoms

Anions are bigger than atoms

2. Ionization Energy

- Ionization energy tends to decrease down a group in the periodic table.
  - For atoms in the same group, effective nuclear charge (Z_{eff}) is essentially the same, but the valence electrons are farther from the nucleus, more easily it can be removed.

- Ionization energy tends to increases from left to right across a period.
  - As we go from left to right, the Z_{eff} increases. The valence electrons are more tightly held.



Anomalies in trends of first I.P.

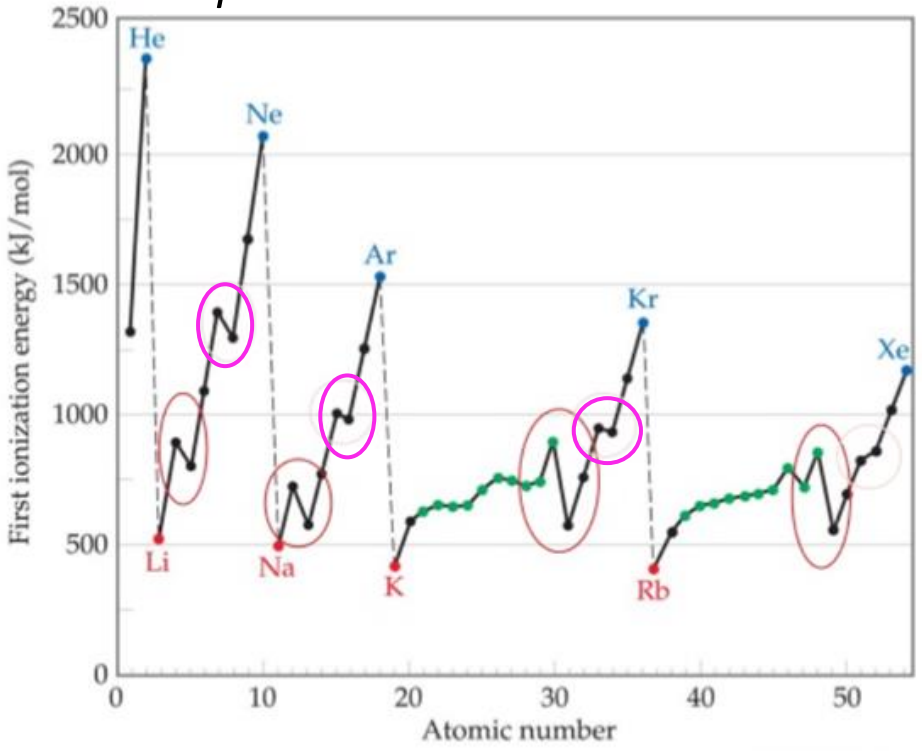
- The first anomaly occurs between group IIA (2) and IIIA (3) (**e.g. Be and B**)
  - Electron is removed from *p*-orbital, rather than *s*-orbital. Being less penetrating than *s*-orbital, the *p*-orbitals are more screened by the inner core; hence, removing electron from *p*-orbital is easier.

Be: $1s^2$, $2s^2$

B: $1s^2$, $2s^2$, $2p^1$

N: $1s^2$, $2s^2$, $2p^3$

O: $1s^2$, $2s^2$, $2p^4$



- The second anomaly occurs between groups VA (15) and VIA (16) (e.g. N and O).
  - The electron is removed from doubly occupied orbital. Repulsion from other electron in the same orbital helps its removal.

3. Trends in Electronegativity

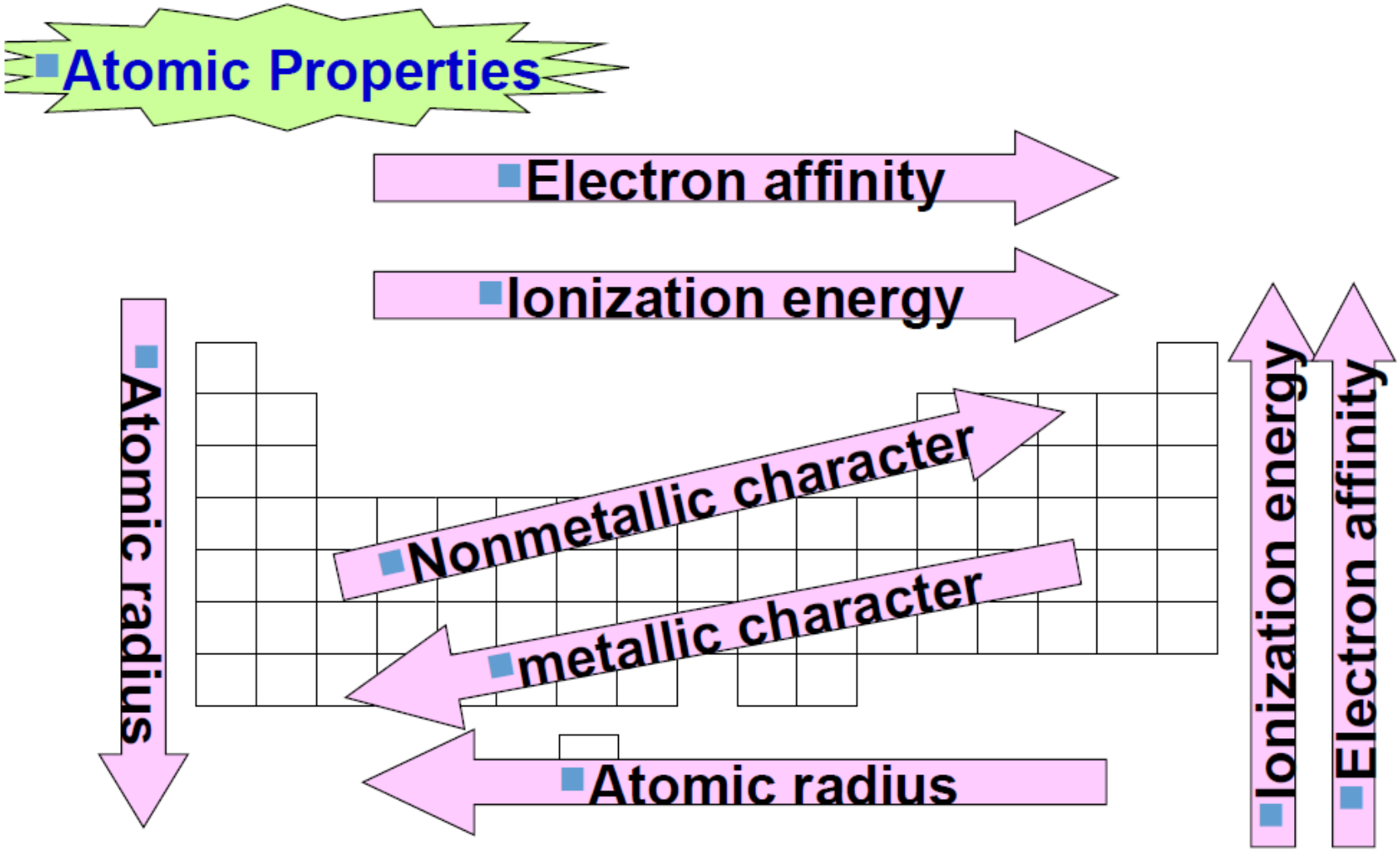
- Electronegativity is the ability of an atom to attract electrons to itself.
- Electronegativity decreases from top to bottom and increases from left to right of the periodic table.

4. Trends in Electron Affinity

- Electron affinity is the amount of energy released or exerted when an atom gains an electron in its gaseous state.
- Down a group the electron affinity of the elements decreases.
- Electron Affinity increases within a period (left to right)

Summary of Chemical Periodicity

- Periodic Properties of the elements



- Atomic properties and the periodic table a summary

- **Question:** Fluorine is more electronegative than chlorine, but the electron affinity of chlorine is greater than fluorine. Why?

Answer: This is due to the very small size of fluorine atom, which results in a very high charge density and consequently strong repulsion between the existing and entering electrons.

Questions

1. What is a periodic table? What its is useful for?
2. Which part of the periodic table is called s- block and p-block?
3. Which elements / group in periodic table is called alkali metals, alkaline earth metals, halogens, noble gasses?
4. What are the characteristics of metals, non-metals and metalloids? Give example.
5. How does the electronegativity of elements vary in the periodic table? (e.g. along the period (left to right) and along the group (top to bottom).
6. What are the elements are called lanthanides? Why are they called f-block elements?
7. What are called transition metals? Explain with example.

Thank you for your Attention