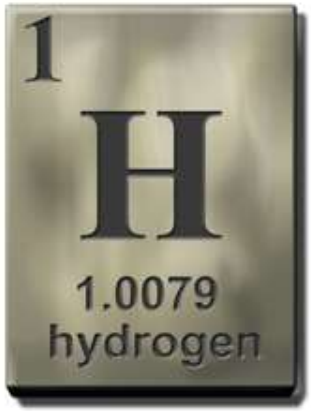
CHAPTER 6

A NATURAL APPROACH TO CHEMISTRY

Elements and the Periodic Table

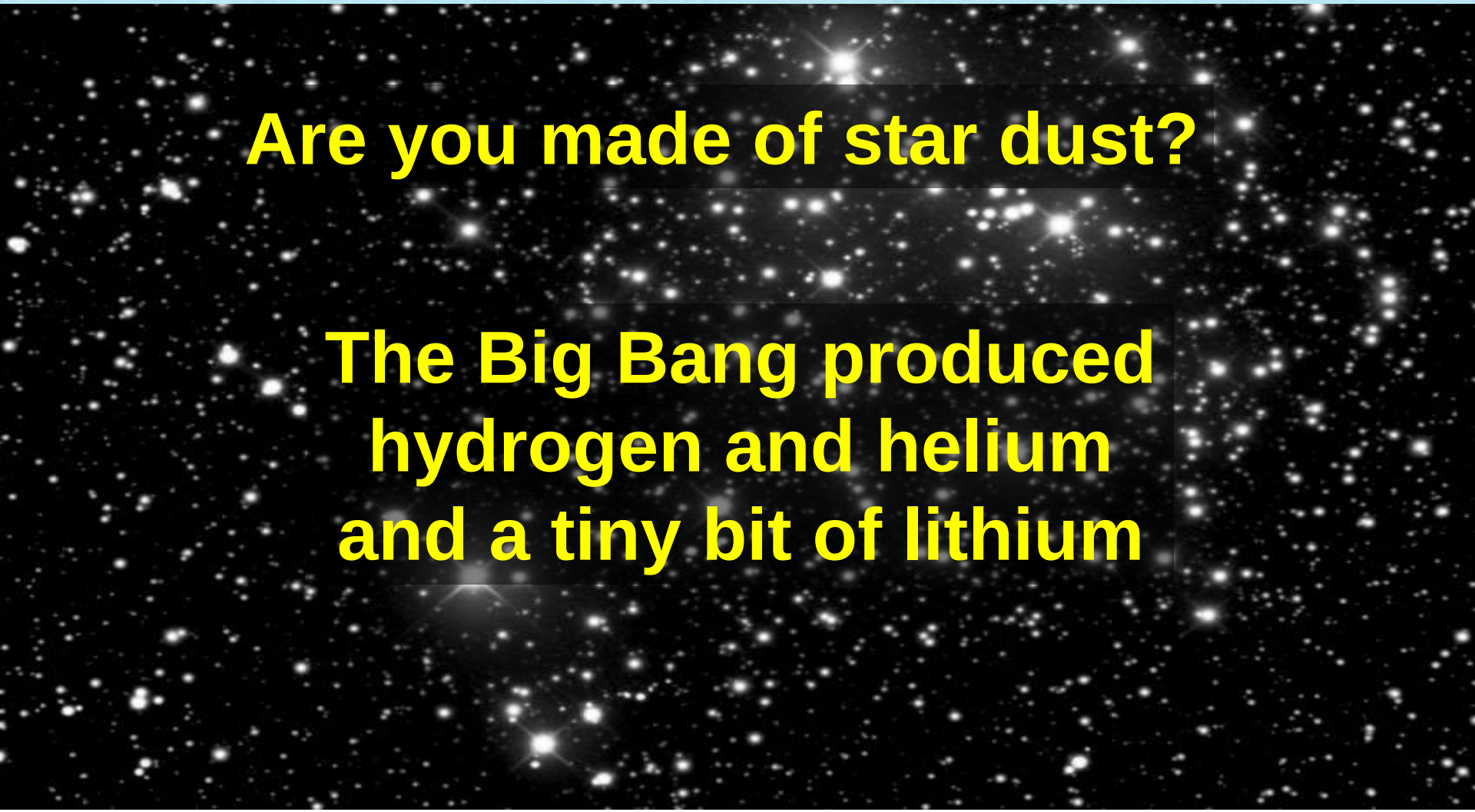


6.1 The Periodic Table

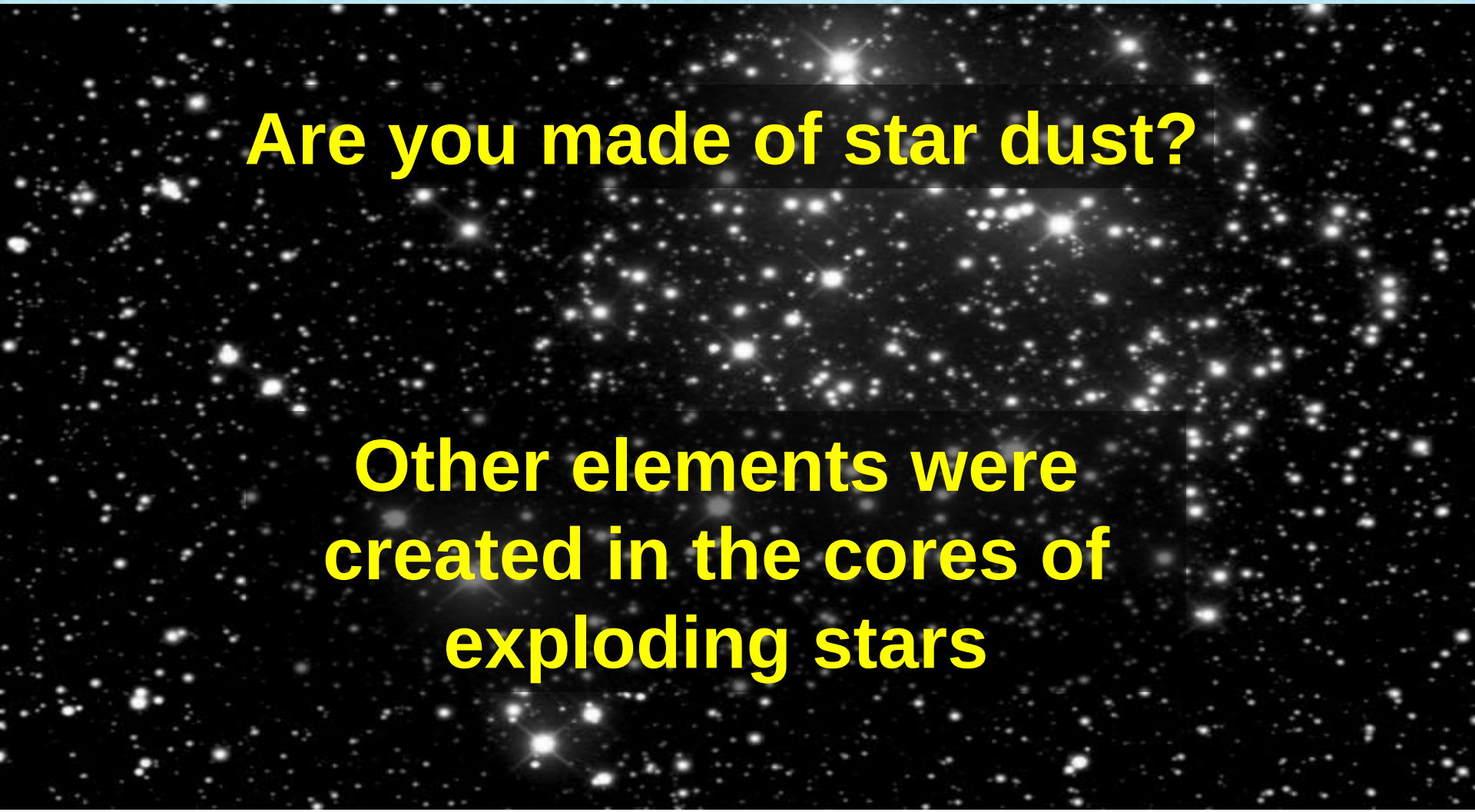
LAB-AIDS

Questions

Questions


Are you made of star dust?
The Big Bang produced hydrogen and helium and a tiny bit of lithium

Questions


Are you made of star dust?
Other elements were created in the cores of exploding stars

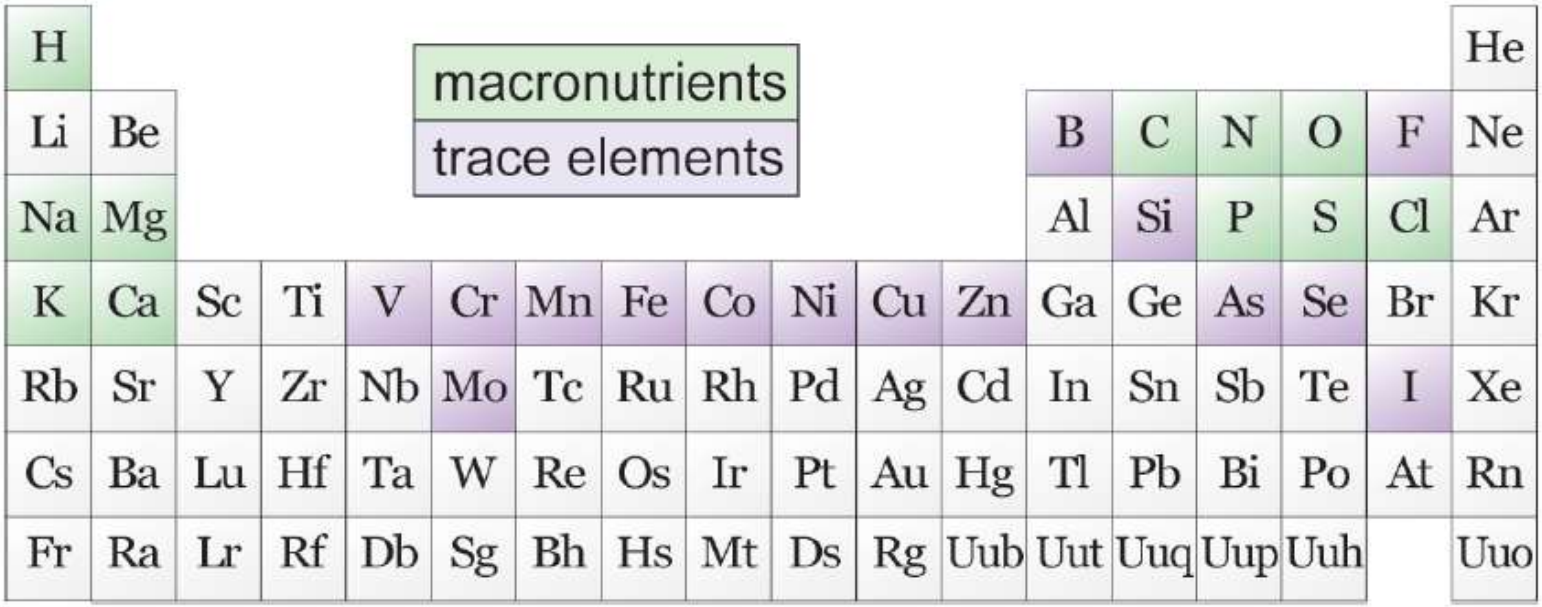
Key Concepts

Element	% by mole
Hydrogen	63.0
Oxygen	26.0
Carbon	9.0
Nitrogen	1.25
Calcium	0.25
Phosphorus	0.19
Potassium	0.06
Sulfur	0.06
Sodium	0.04
Chlorine	0.025
Magnesium	0.013
Iron	0.00004
Iodine	0.000002

99% of atoms in a human body come from only 4 elements

Key Concepts

Essential elements



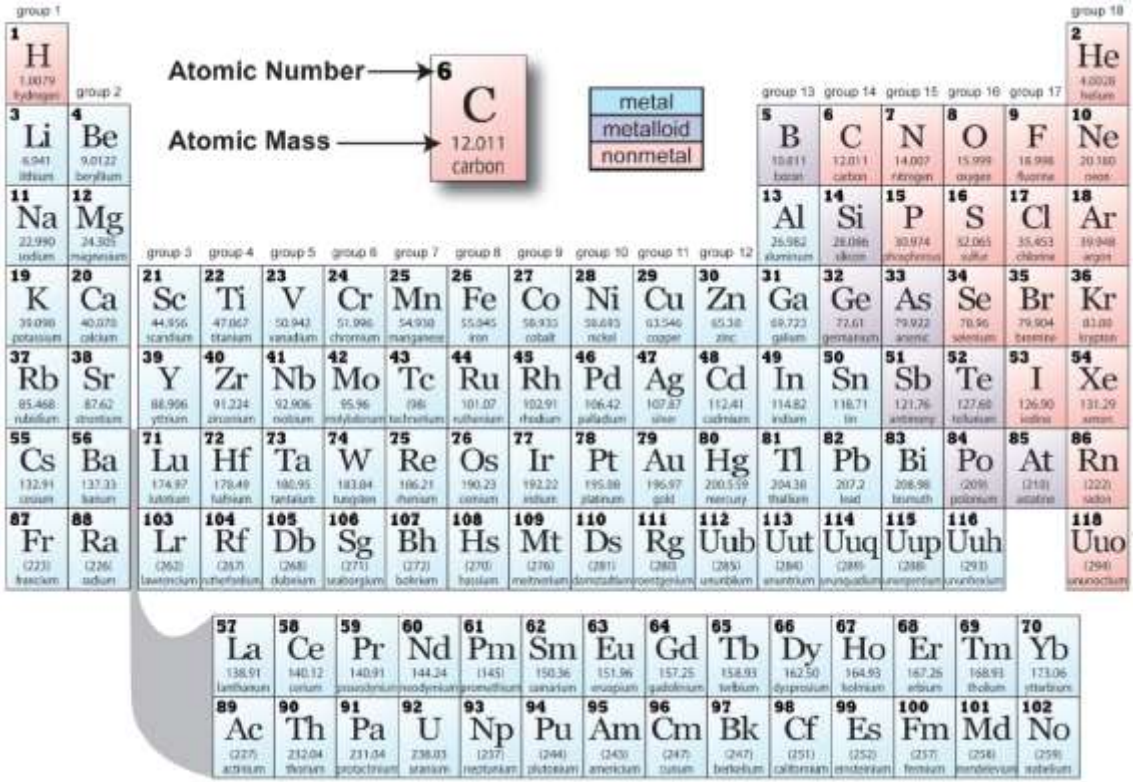
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh		Uuo

macronutrients: elements needed in large quantities by your body.

trace elements: elements that are needed in very small quantities to maintain optimum health.

Review

Metals, nonmetals and metalloids

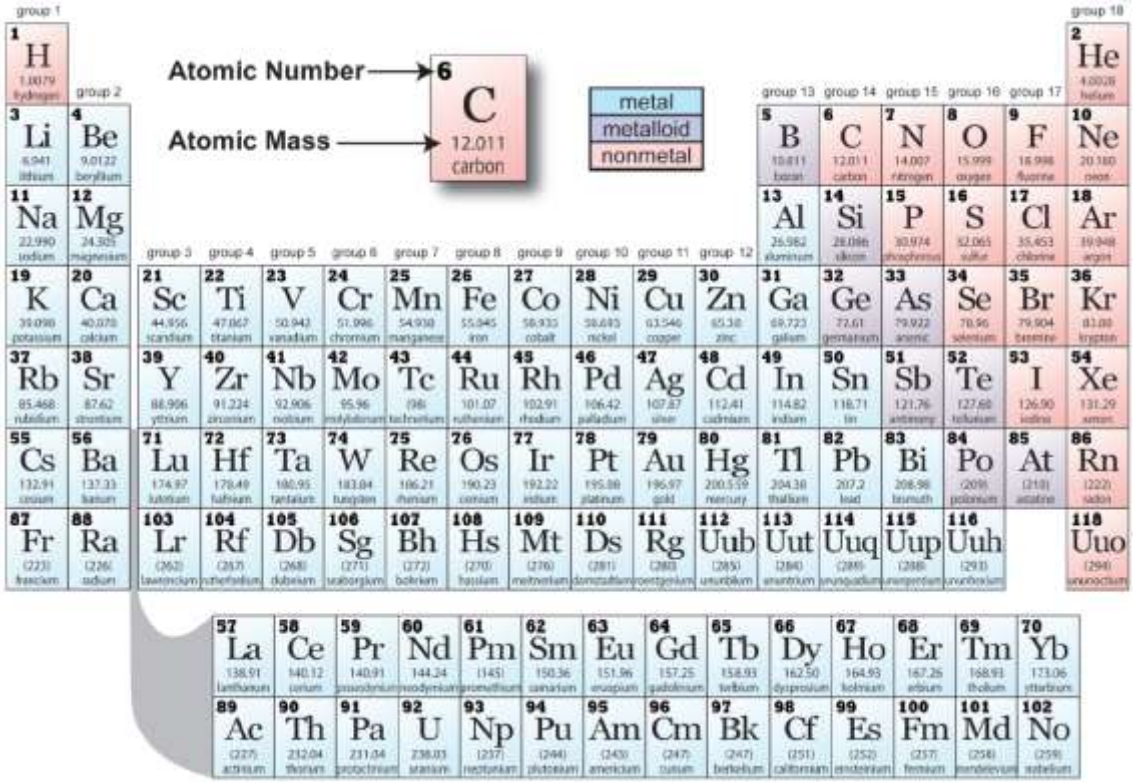


ionic compound:
one non-metal atom bonded with one metal atom

molecular compound:
two non-metal atoms bonded with each other

Questions

Metals, nonmetals and metalloids

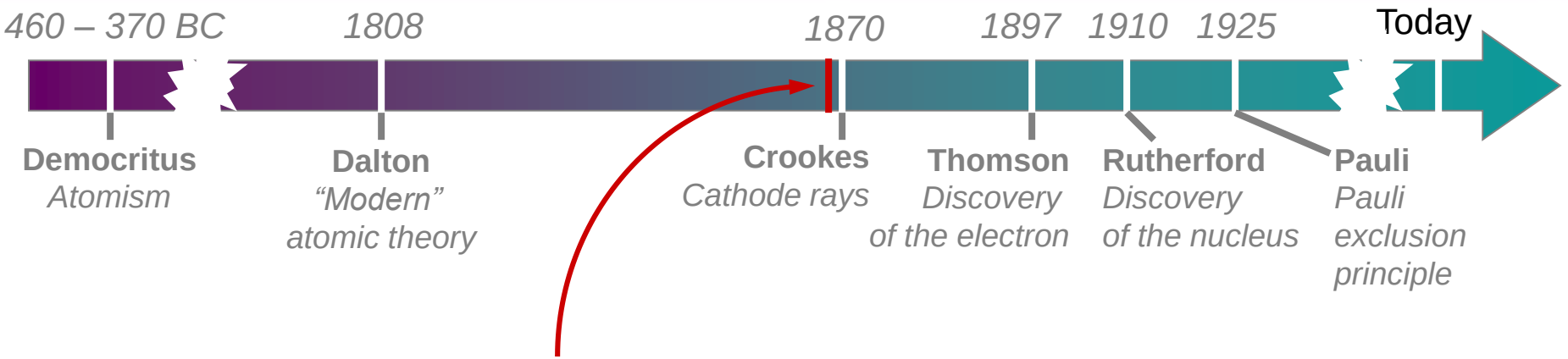


ionic compound:
one non-metal atom bonded with one metal atom

molecular compound:
two non-metal atoms bonded with each other

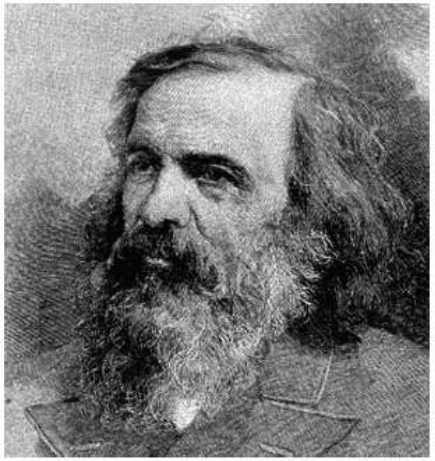
What does “periodic” in “periodic table” mean?

Key Concepts



1869

Mendeleev looks for a logical way to organize the elements known at the time.



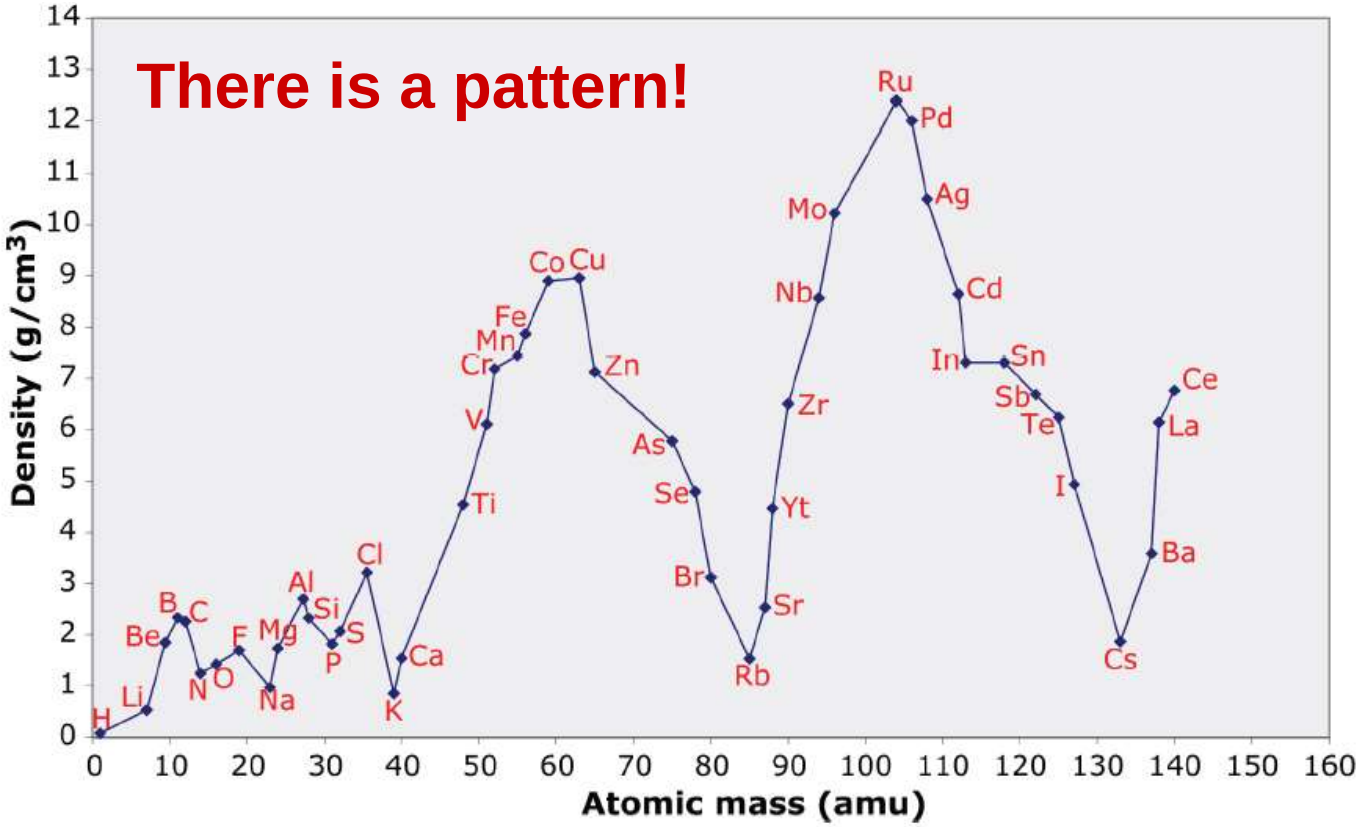
Dimitri Mendeleev

Note that at this time, very little is known about atoms.

Protons and atomic numbers were not discovered yet.

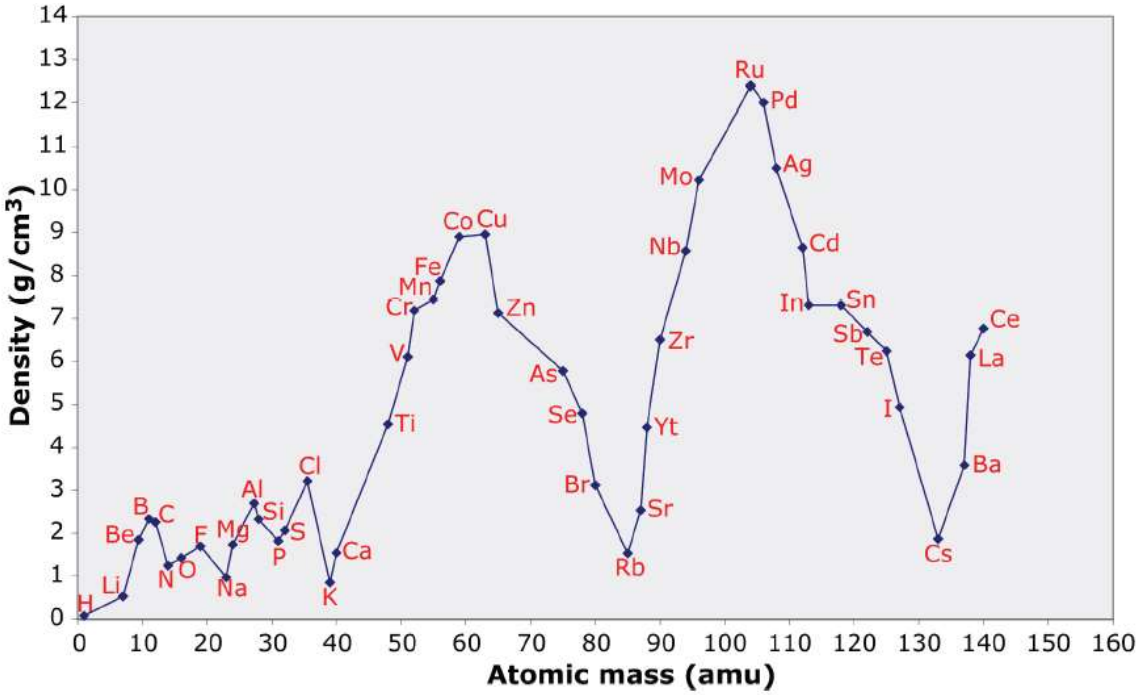
Key Concepts

Mendeleev uses density (a physical property) of atoms, and organizes them in order of increasing atomic mass.



Vocabulary

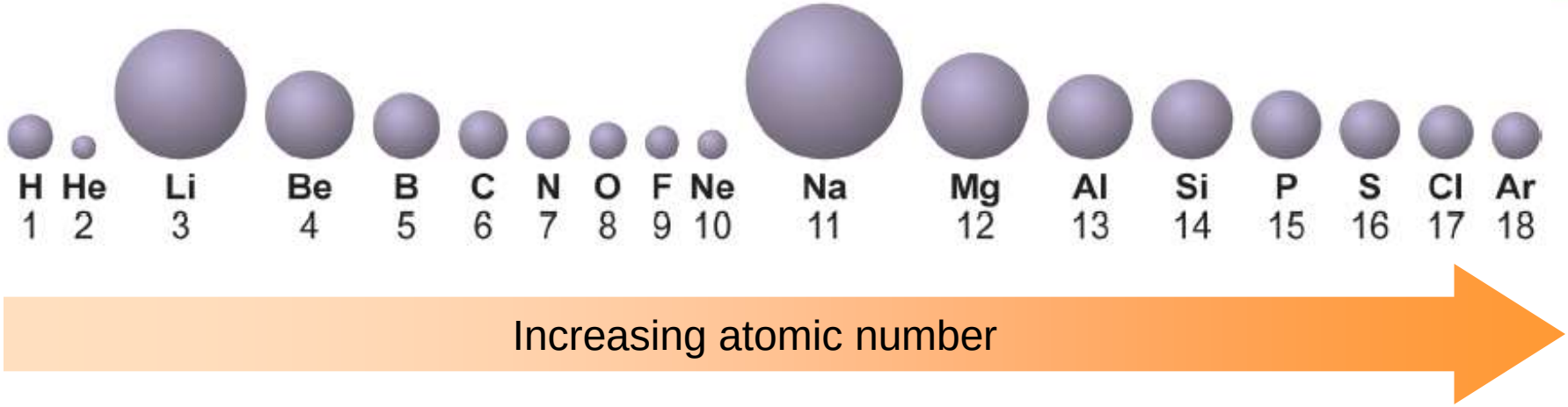
The **periodic** table contains patterns that repeat at regular intervals



periodic: repeating at regular intervals.

Key Concepts

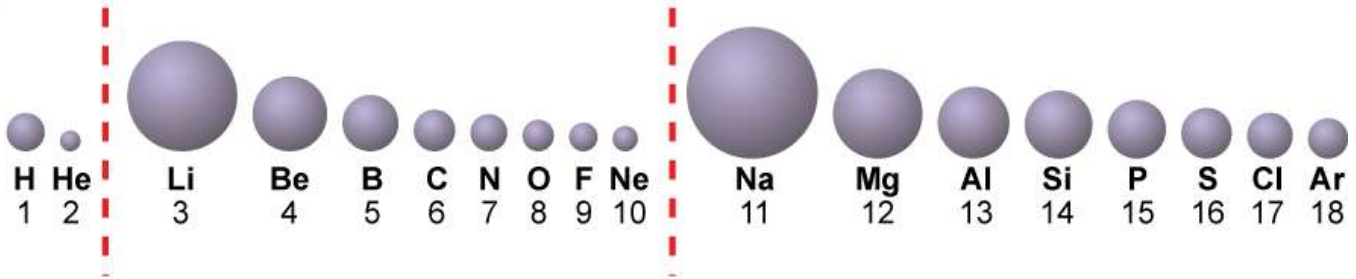
Atomic radius



Like for density, there is a **repeating pattern** in atomic radii.

Key Concepts

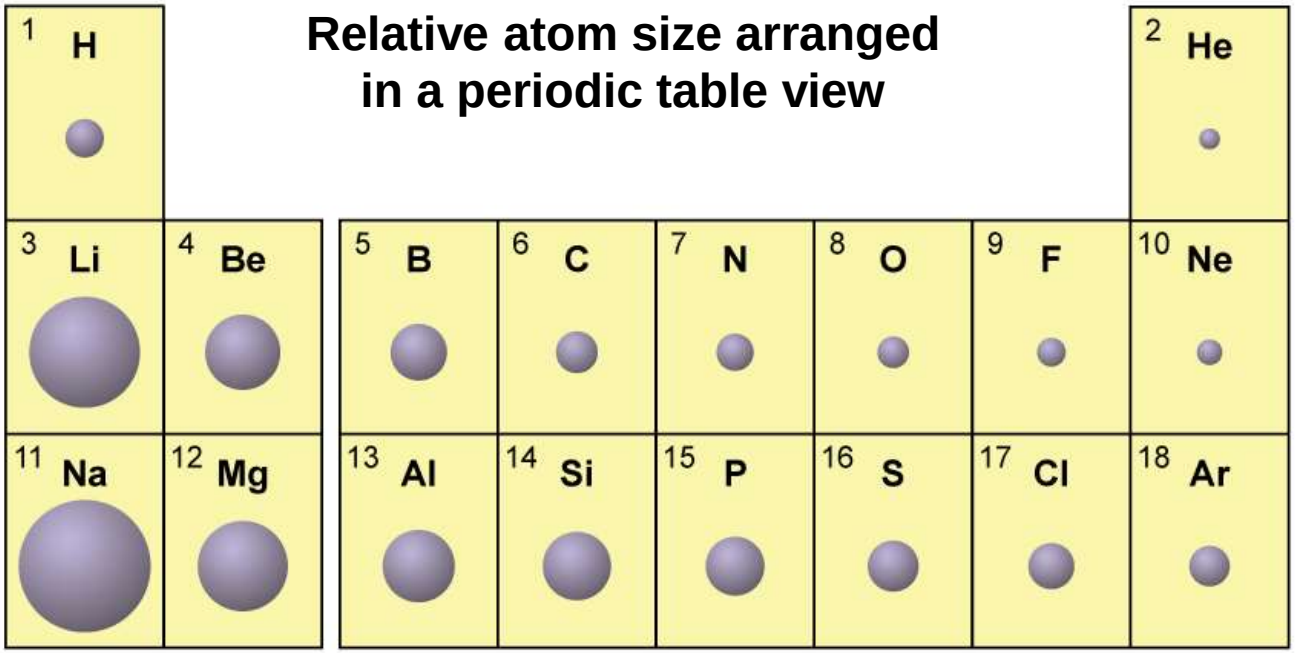
Atomic radius



Relative atom size arranged in a periodic table view

A new period

A new period



Atomic radius

atomic radius: the distance from the center of an atom to its “outer edge.”

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh		Uuo

small  **large**

Electronegativity

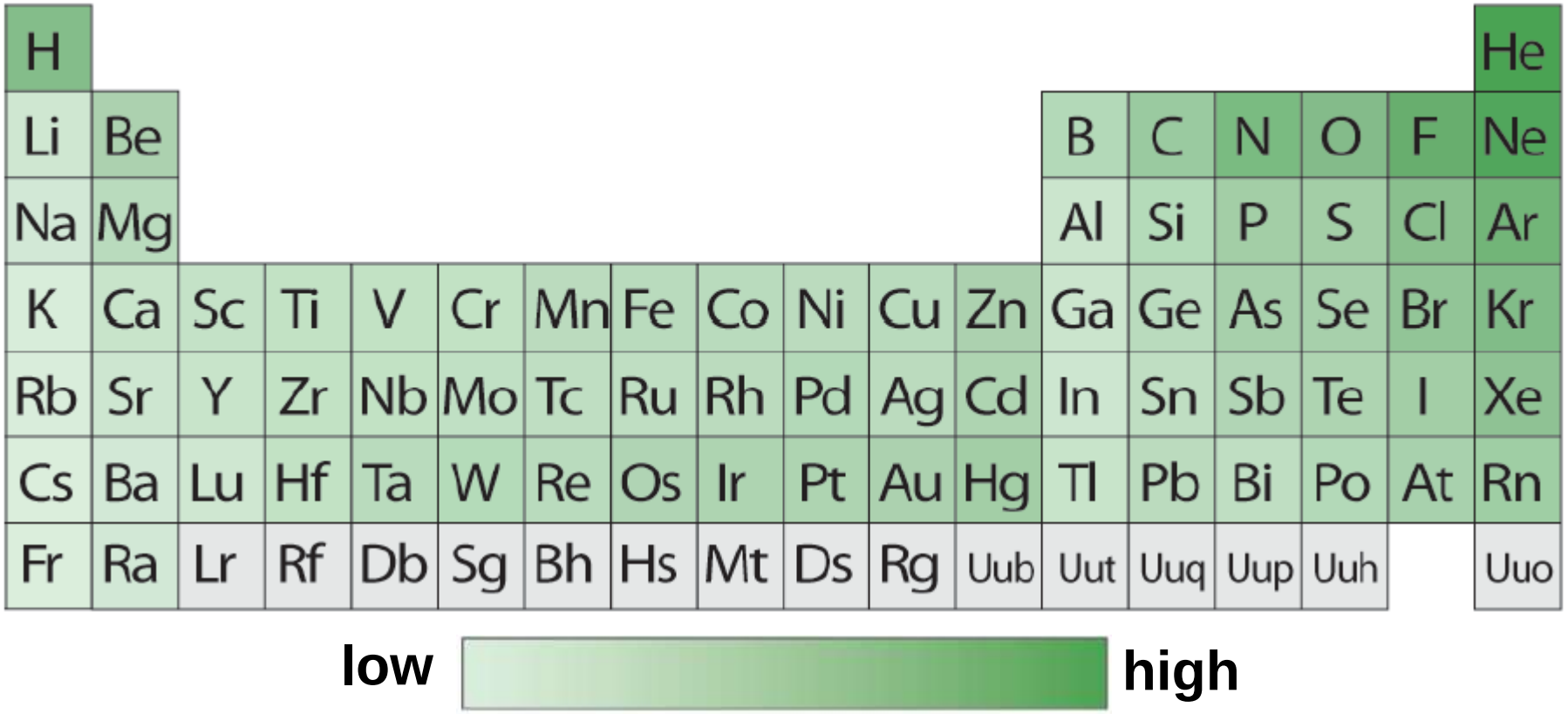
electronegativity: the ability of an atom to attract another atom's electrons when bound to that other atom.

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Uub	Uut	Uuq	Uup	Uuh		Uuo

low **high**

Ionization energy

ionization energy: the energy required to remove an electron from an atom.

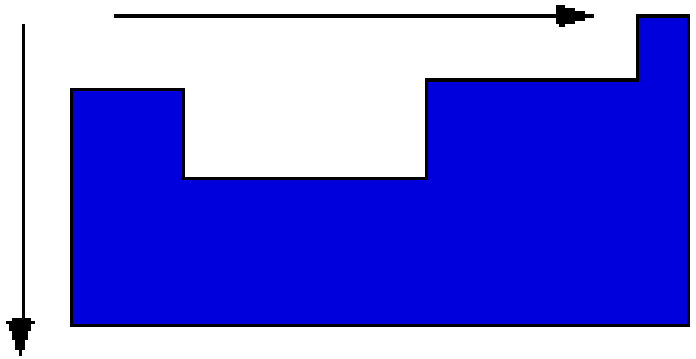


General Periodic Trends

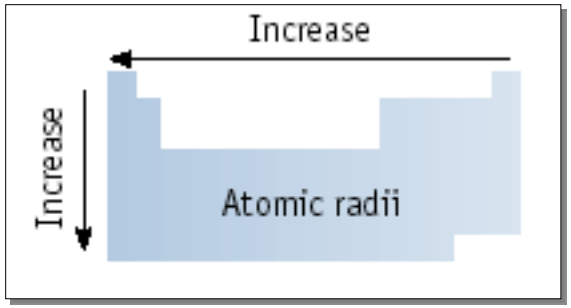
- Atomic and ionic size
- Ionization energy
- Electronegativity

Higher effective nuclear charge
Electrons held more tightly

Larger orbitals.
Electrons held less tightly.



Atomic Size



- Size goes UP on going down a group.
- Because electrons are added further from the nucleus, there is less attraction. This is due to additional energy levels and the shielding effect. Each additional energy level "shields" the electrons from being pulled in toward the nucleus.
- Size goes DOWN on going across a period.

Atomic Size

Size **decreases** across a period owing to increase in the positive charge from the protons. Each added electron feels a greater and greater + charge because the protons are pulling in the same direction, where the electrons are scattered.

Large **Small**

Which is Bigger?

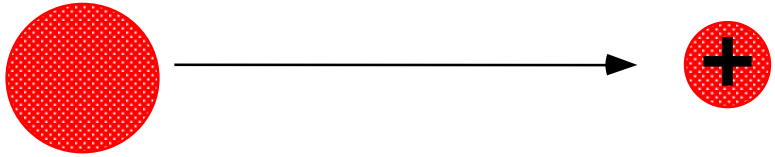
- Na or K ?
- Na or Mg ?
- Al or I ?

Ion Sizes

Li,152 pm
3e and 3p

Does the size go up or down when losing an electron to form a cation?

Ion Sizes



Li,152 pm
3e and 3p

Li^+, 78 pm
2e and 3 p

Forming a cation.

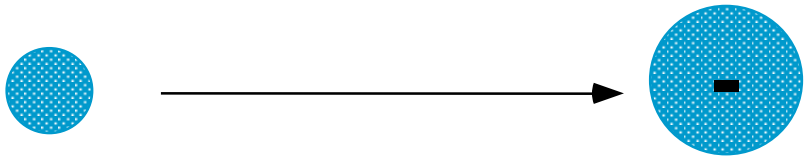
- CATIONS are SMALLER than the atoms from which they come.
- The electron/proton attraction has gone UP and so size DECREASES.

Ion Sizes

F,64 pm
9e and 9p

Does the size go up or down when gaining an electron to form an anion?

Ion Sizes



F, 71 pm
9e and 9p

F^- , 133 pm
10 e and 9 p

Forming an anion.

- ANIONS are LARGER than the atoms from which they come.
- The electron/proton attraction has gone DOWN and so size INCREASES.
- Trends in ion sizes are the same as atom sizes.

Trends in Ion Sizes

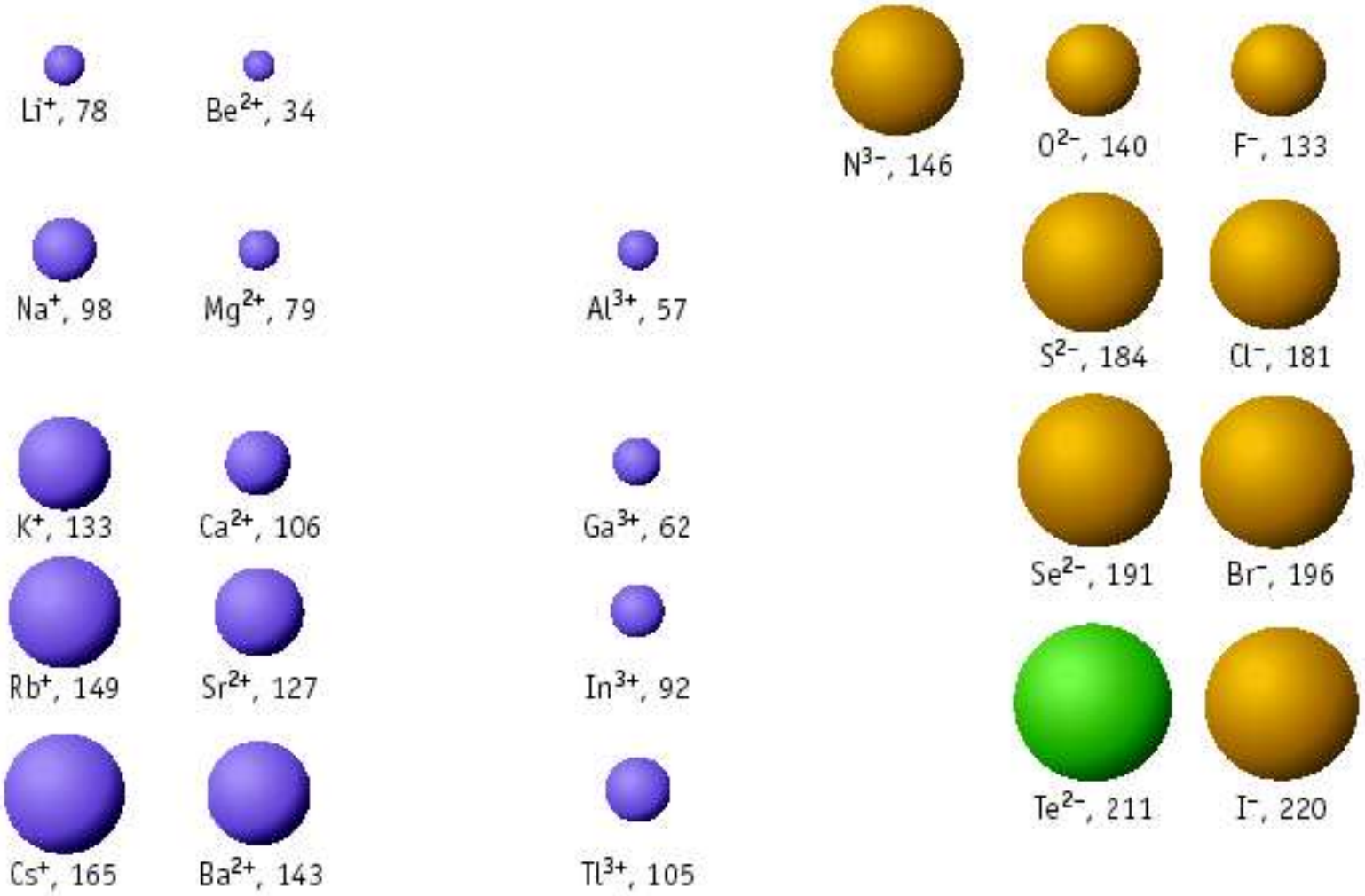


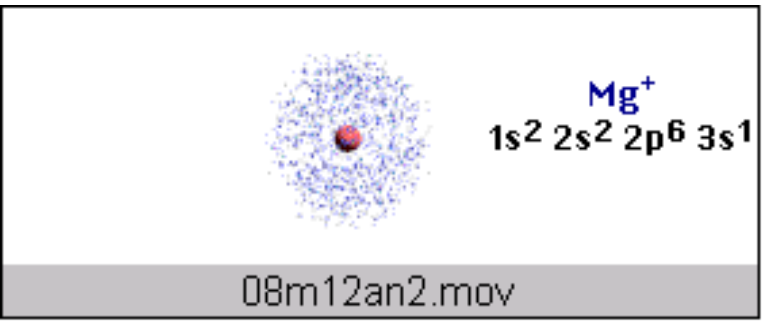
Figure 8.13

Which is Bigger?

- Cl or Cl^- ?
- K^+ or K ?
- Ca or Ca^{+2} ?
- I^- or Br^- ?

Ionization Energy

IE = energy required to remove an electron from an atom (in the gas phase).



$Mg\ (g) + 738\ kJ \rightarrow Mg^+ (g) + e^-$

This is called the FIRST ionization energy because we removed only the OUTERMOST electron

$Mg^+\ (g) + 1451\ kJ \rightarrow Mg^{2+}\ (g) + e^-$

This is the SECOND IE.

Trends in Ionization Energy

- IE increases across a period because the positive charge increases.
- Metals lose electrons more easily than nonmetals.
- Nonmetals lose electrons with difficulty (they like to GAIN electrons).

Trends in Ionization Energy

- IE increases UP a group
- Because size increases (Shielding Effect)

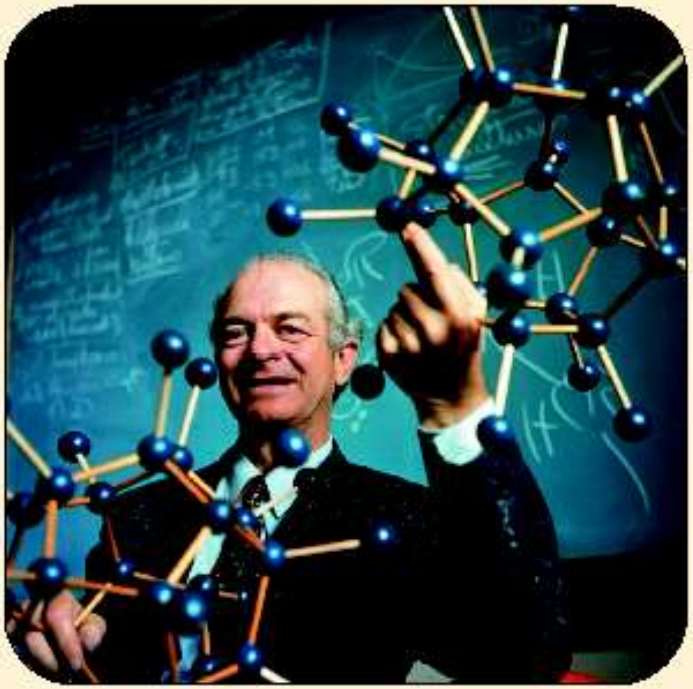
Which has a higher 1st ionization energy?

- Mg or Ca ?
- Al or S ?
- Cs or Ba ?

Electronegativity, χ

χ is a measure of the ability of an atom in a molecule to attract electrons to itself.

Concept proposed by
Linus Pauling
1901-1994



▲ Linus Pauling 1901–1994 *(Thomas Hollyman/ Photo Researchers, Inc.)*

Periodic Trends: Electronegativity

- *In a group:* Atoms with fewer energy levels can attract electrons better (less shielding). So, electronegativity increases UP a group of elements.
- *In a period:* More protons, while the energy levels are the same, means atoms can better attract electrons. So, electronegativity increases RIGHT in a period of elements.

Electronegativity

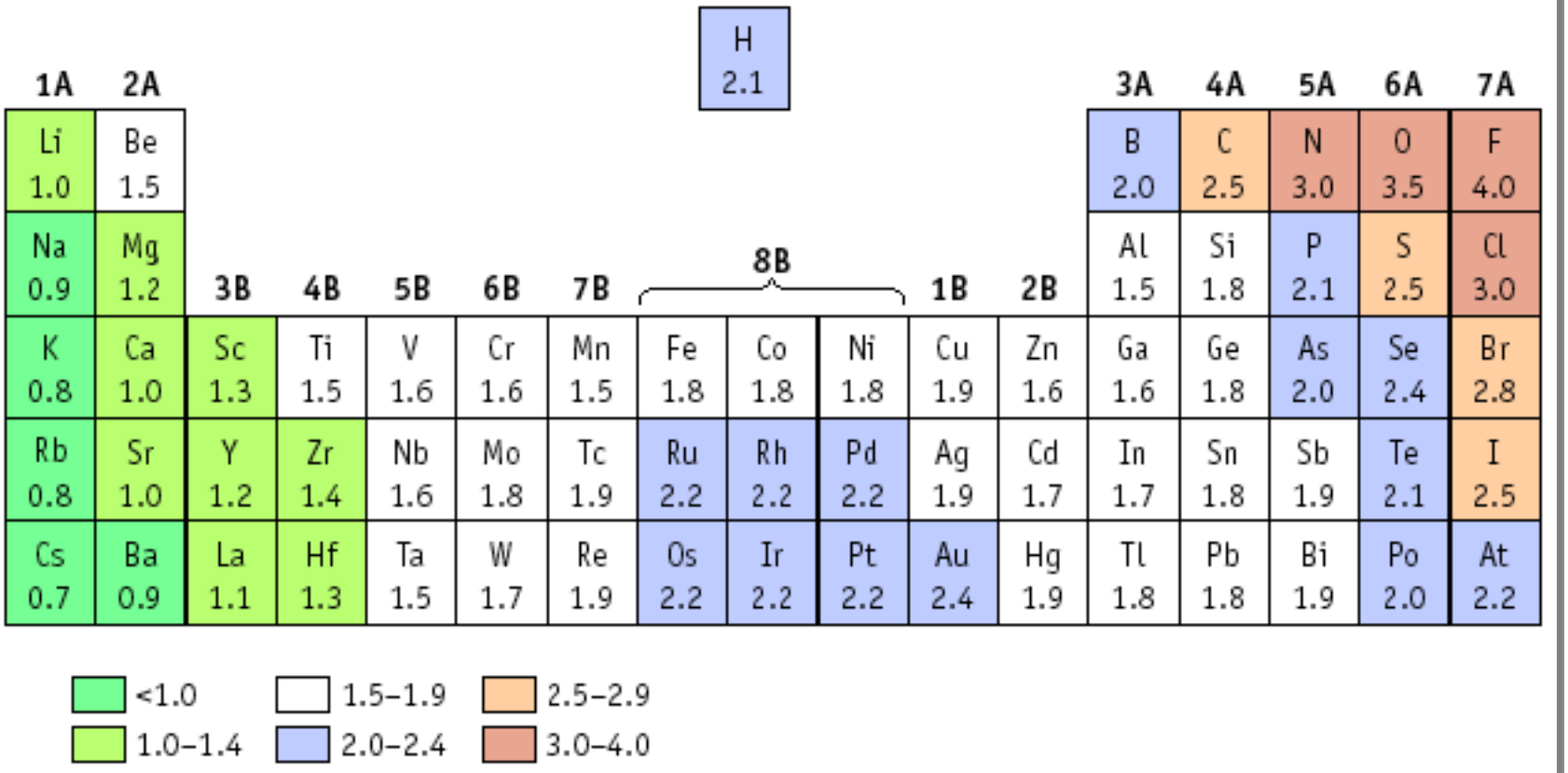
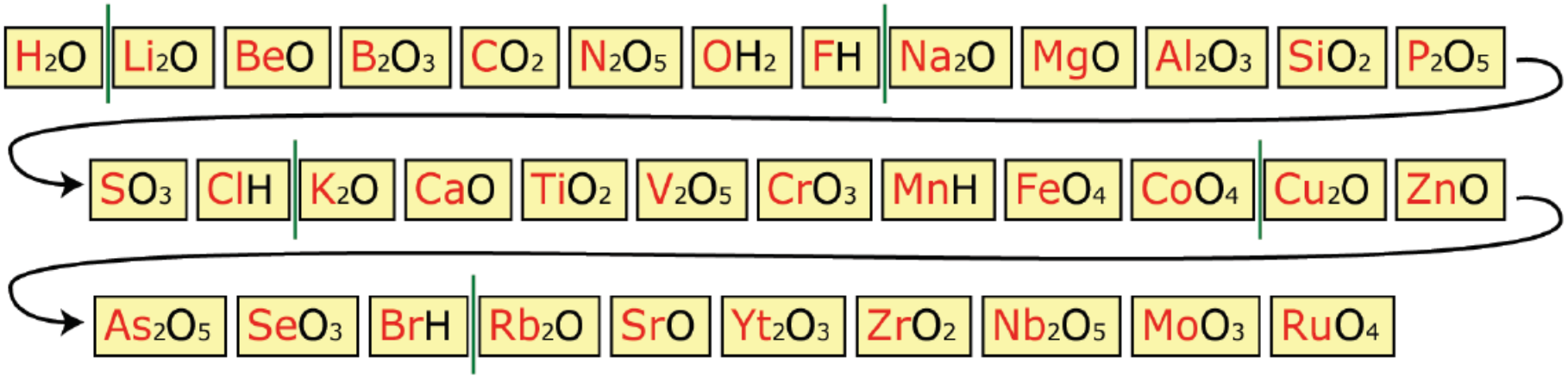


Figure 9.9 Electronegativity values for the elements according to Pauling. Trends for electronegativities are the opposite of the trends defining metallic character. Nonmetals have high values of electronegativity, the metalloids have intermediate values, and the metals have low values.

Which is more electronegative?

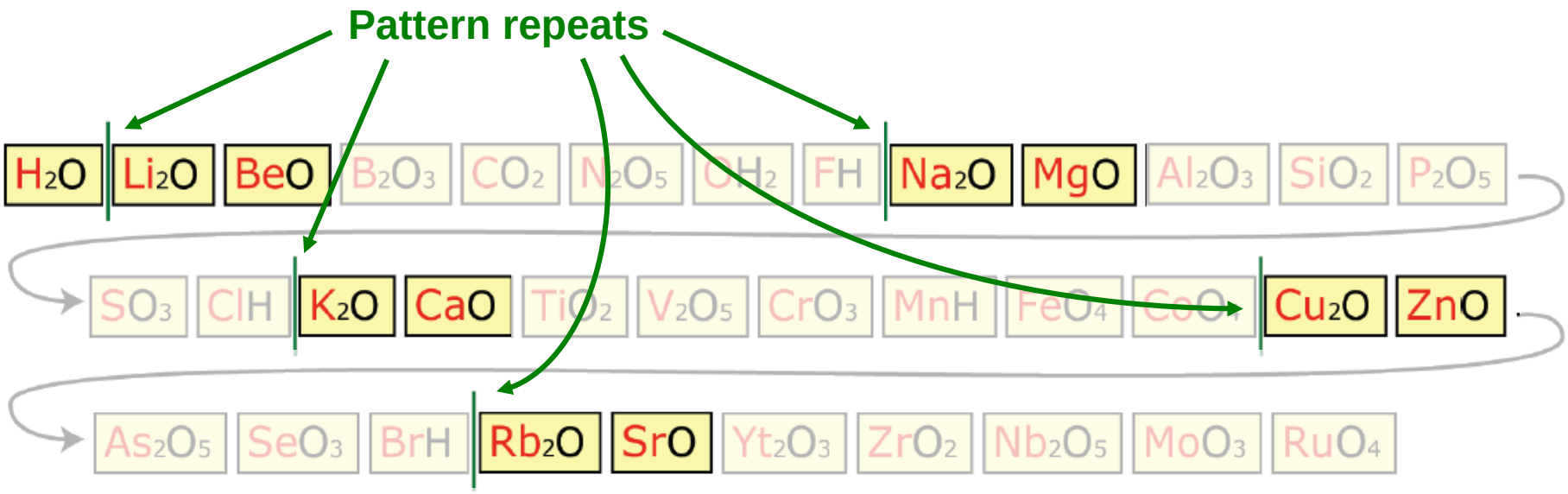
- F or Cl ?
- Na or K ?
- Sn or I ?

The first periodic table



Mendeleev placed the elements in order of increasing atomic mass and then noticed a repeating pattern in the oxide and hydride formula.

The first periodic table



Mendeleev placed the elements in order of increasing atomic mass and then noticed a repeating pattern in the oxide and hydride formula.

A new pattern was discovered!

The first periodic table

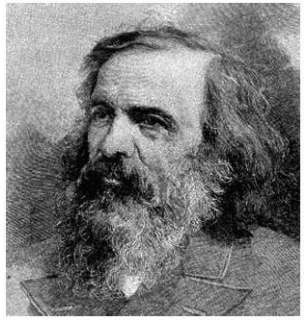
Oxides and hydrides sorted into rows:

H_2O								
Li_2O	BeO	B_2O_3	CO_2	N_2O_5	OH_2	FH		
Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClH		
K_2O	CaO		TiO_2	V_2O_5	CrO_3	MnH	FeO_4	CoO_4
Cu_2O	ZnO			As_2O_5	SeO_3	BrH		
Rb_2O	SrO	Yt_2O_3	ZrO_2	Nb_2O_5	MoO_3		RuO_4	

The first periodic table as suggested by Mendeleev in 1869

Stop and Think

Mendeleev left empty spaces for elements not yet discovered



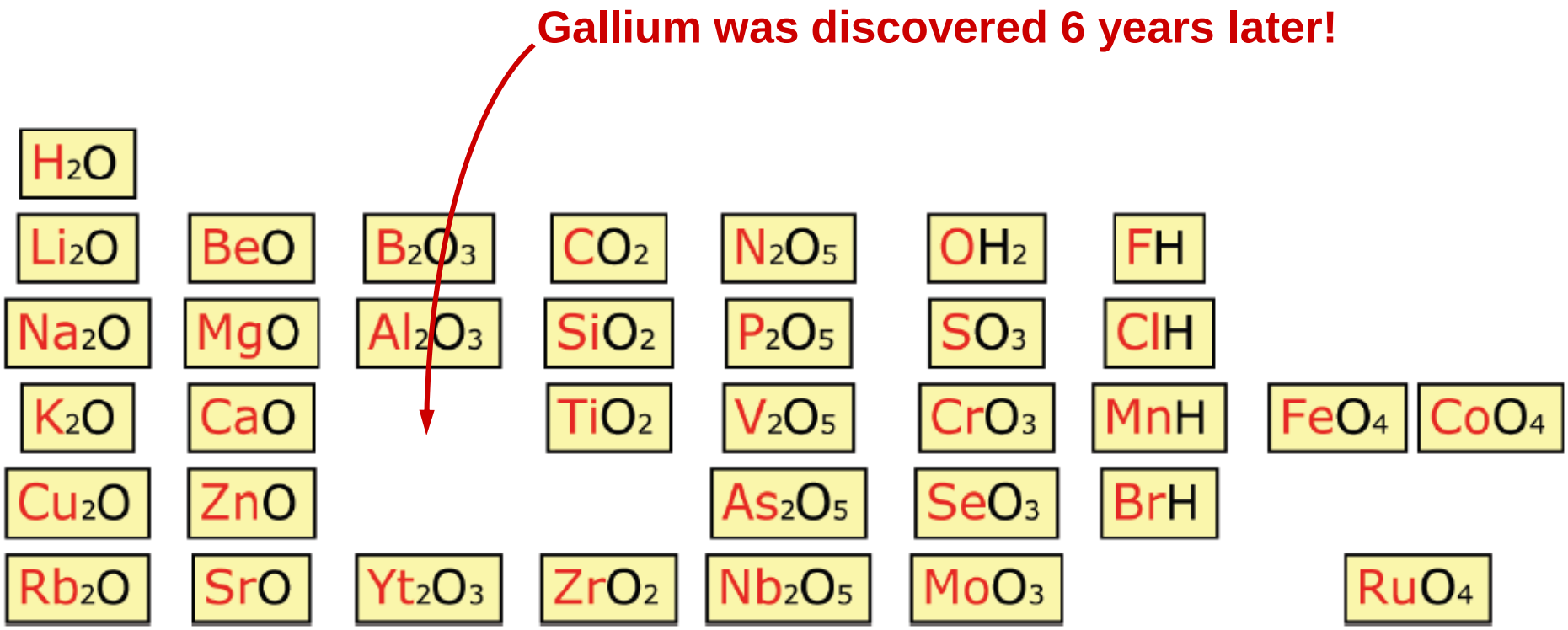
H_2O						
Li_2O	BeO	B_2O_3	CO_2	N_2O_5	OH_2	FH
Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClH
K_2O	CaO		TiO_2	V_2O_5	CrO_3	MnH
Cu_2O	ZnO			As_2O_5	SeO_3	BrH
Rb_2O	SrO	Yt_2O_3	ZrO_2	Nb_2O_5	MoO_3	

FeO_4 CoO_4

RuO_4

The first periodic table as suggested by Mendeleev in 1869

Key Concepts



The first periodic table as suggested by Mendeleev in 1869

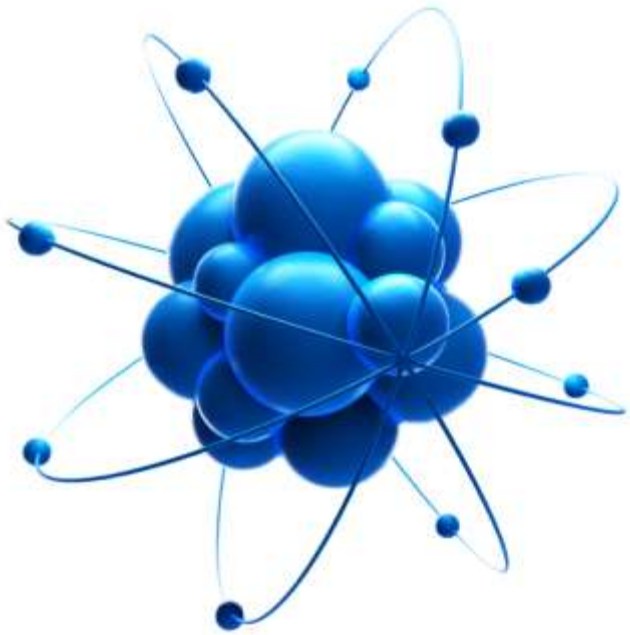
The modern periodic table

The modern periodic table arranges elements in order of **increasing atomic number**, not atomic mass.

Scientists have been adding elements to the periodic table, as more are discovered or created.

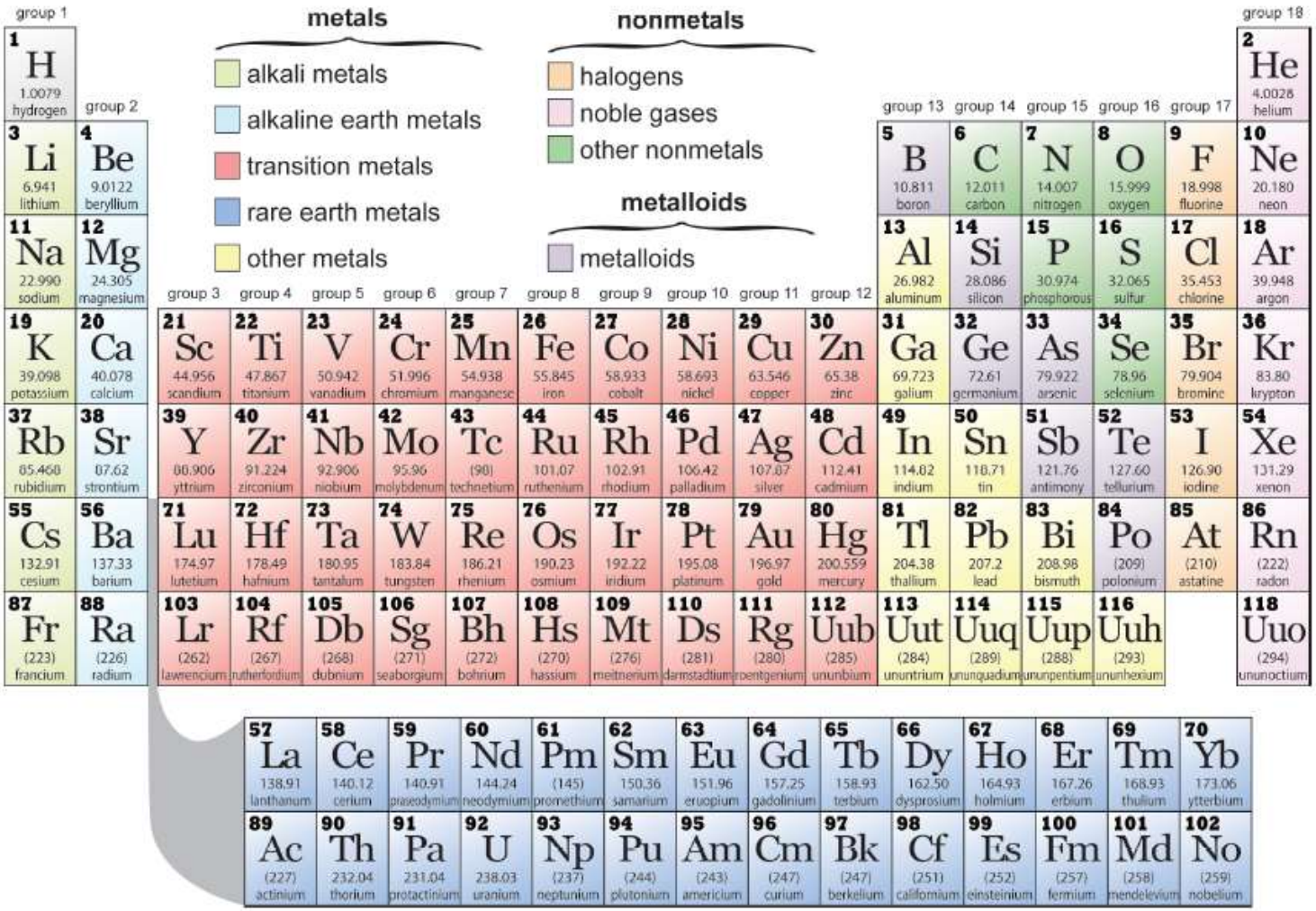
The last naturally occurring element to be discovered is Francium (Fr) in 1939.

70 years after Mendeleev, who had called it *eka-caesium*



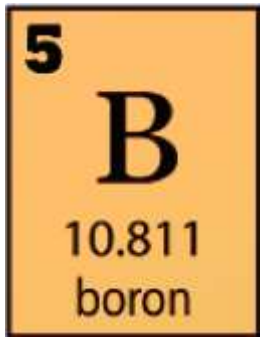
Key Concepts

The modern periodic table

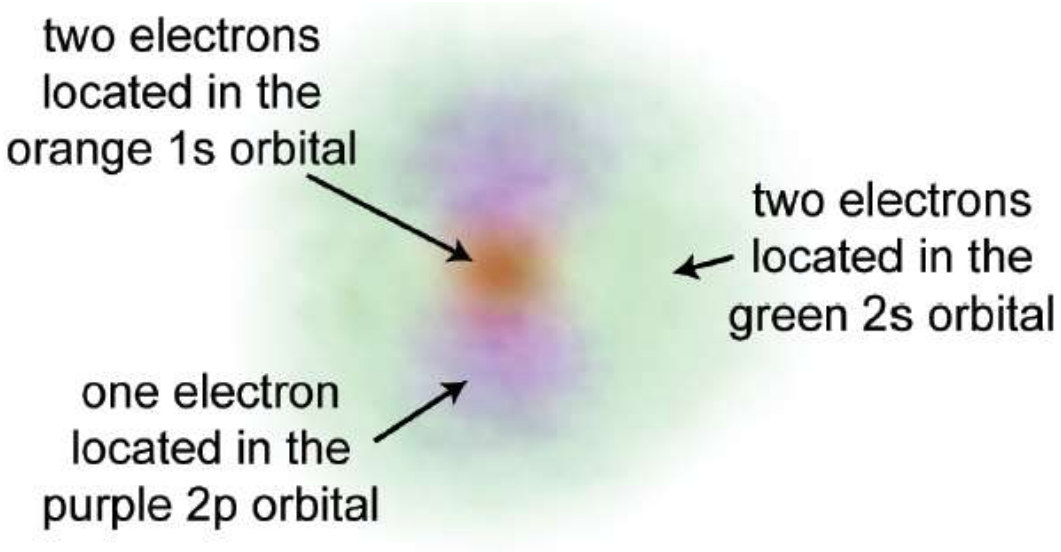


Key Concepts

Electron structure was discovered after the periodic table was developed…



Electron configuration: $1s^2 2s^2 2p^1$

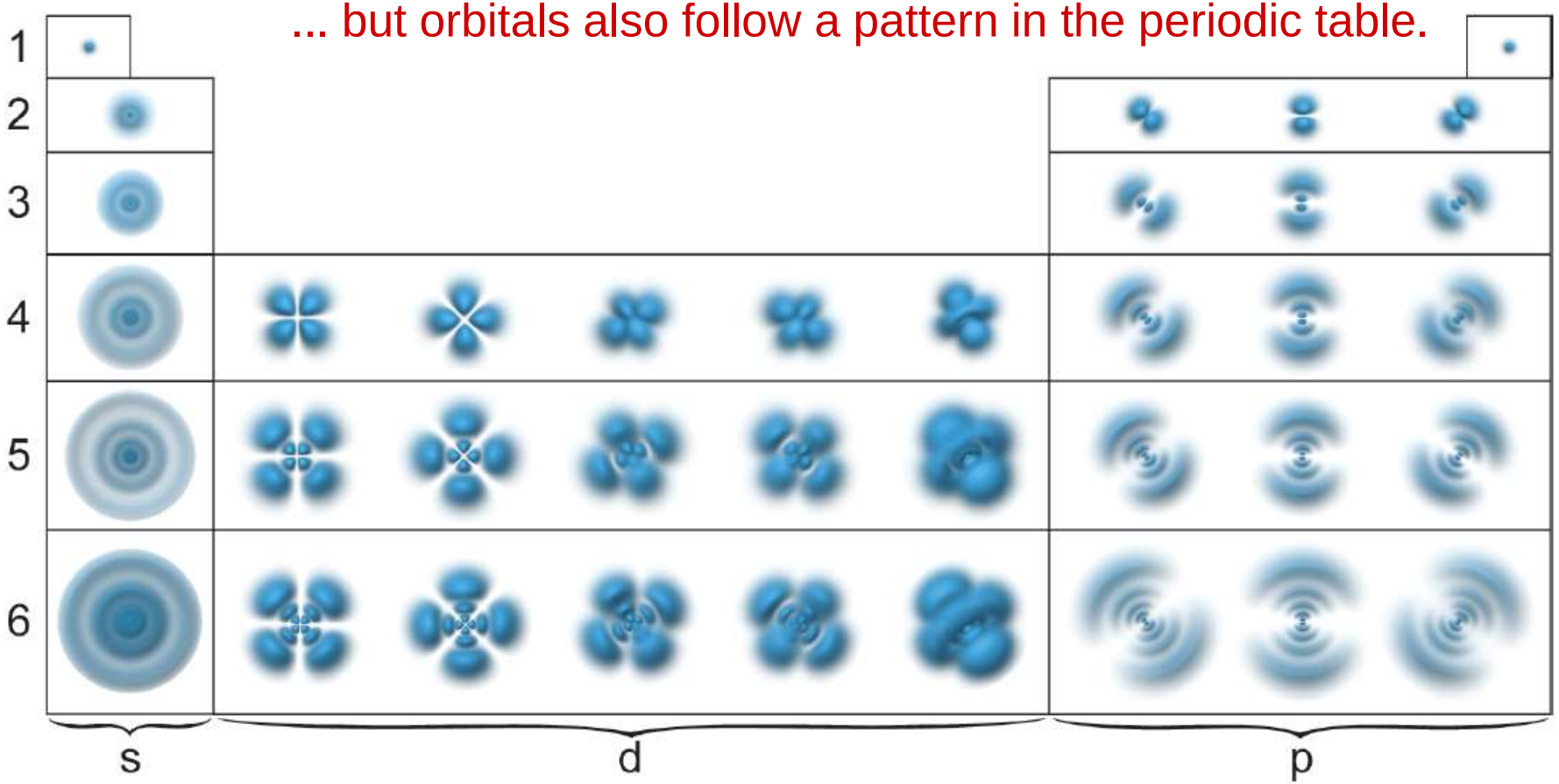


Overlapping orbitals of boron

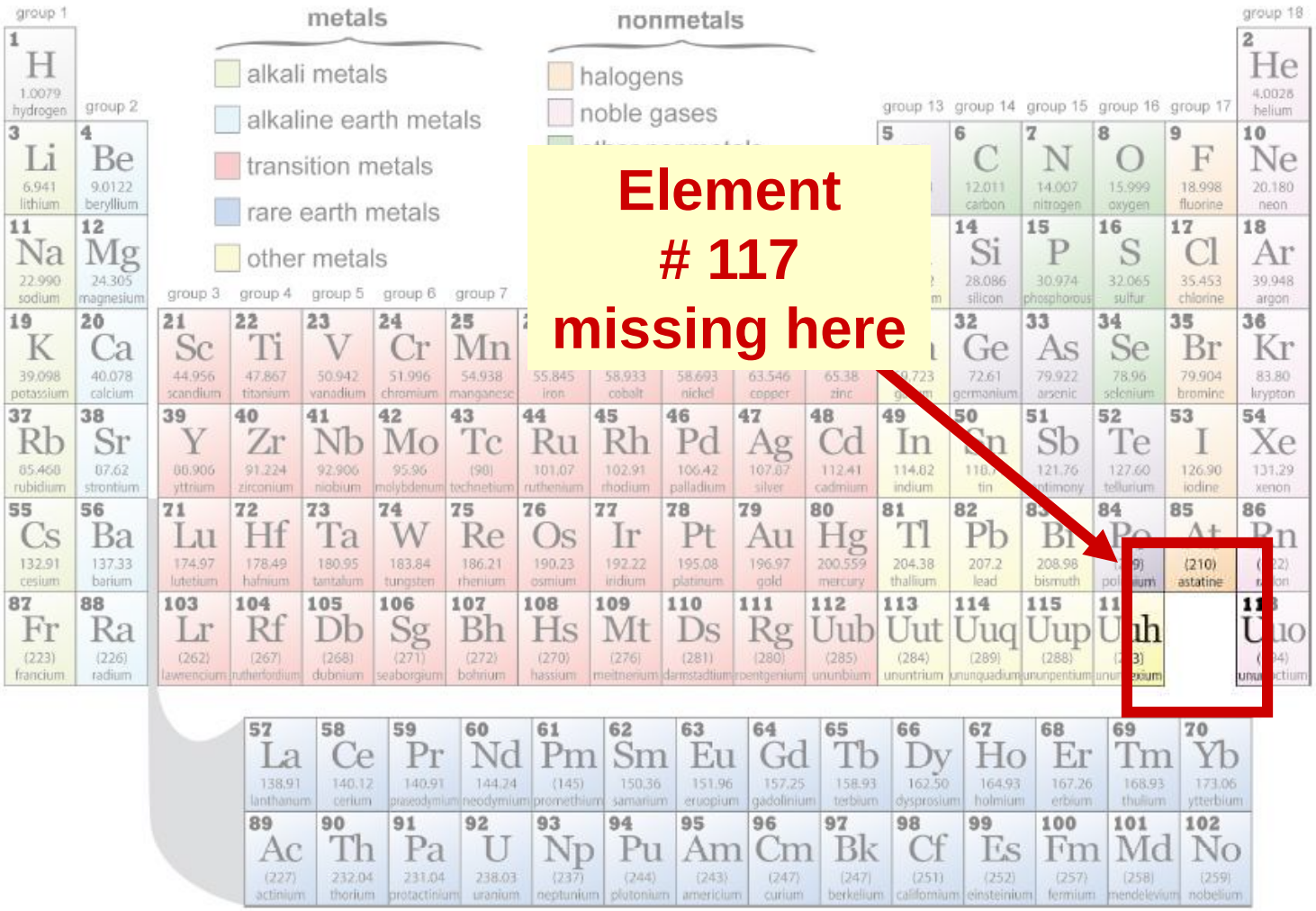
Key Concepts

Electron structure was discovered after the periodic table was developed…

... but orbitals also follow a pattern in the periodic table.



Key Concepts



Key Concepts

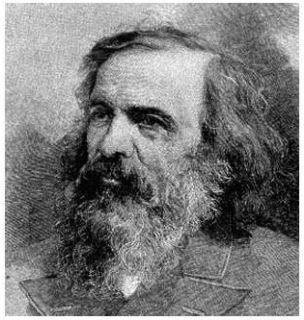
2009-2010

Element #117 was discovered through a Russian-US collaboration.
The discovery still needs to be confirmed.
It is temporarily named ununseptium (Uus).

Discoveries are made all the time!

Summary

Elements in **the first periodic table** were arranged in order of increasing atomic mass



H_2O							
Li_2O	BeO	B_2O_3	CO_2	N_2O_5	OH_2	FH	
Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	ClH	
K_2O	CaO		TiO_2	V_2O_5	CrO_3	MnH	FeO_4 CoO_4
Cu_2O	ZnO			As_2O_5	SeO_3	BrH	
Rb_2O	SrO	Yt_2O_3	ZrO_2	Nb_2O_5	MoO_3		RuO_4

The first periodic table as suggested by Mendeleev in 1869

Summary

Elements in **the modern periodic table** are arranged in order of increasing atomic number

The modern periodic table shows trends or repeating patterns in atomic radii, electronegativity and ionization energy