Periodic Table: Facts and Trends

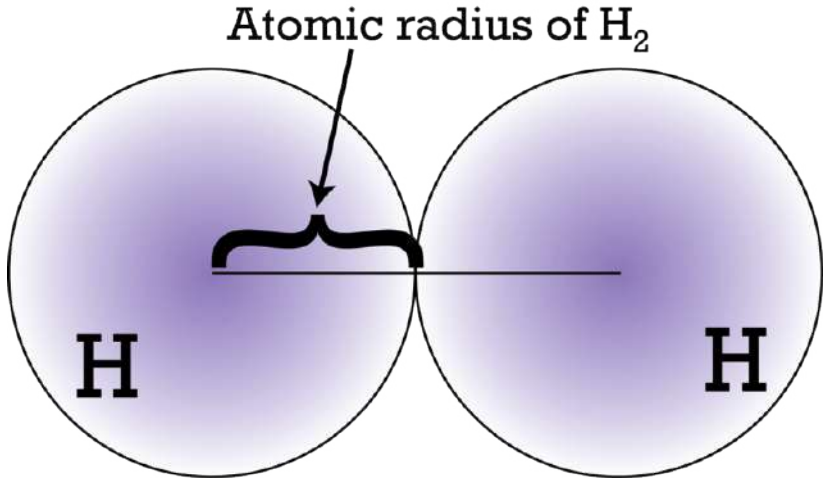
Chemistry
Unit 5 Module 3

Periodic Trends

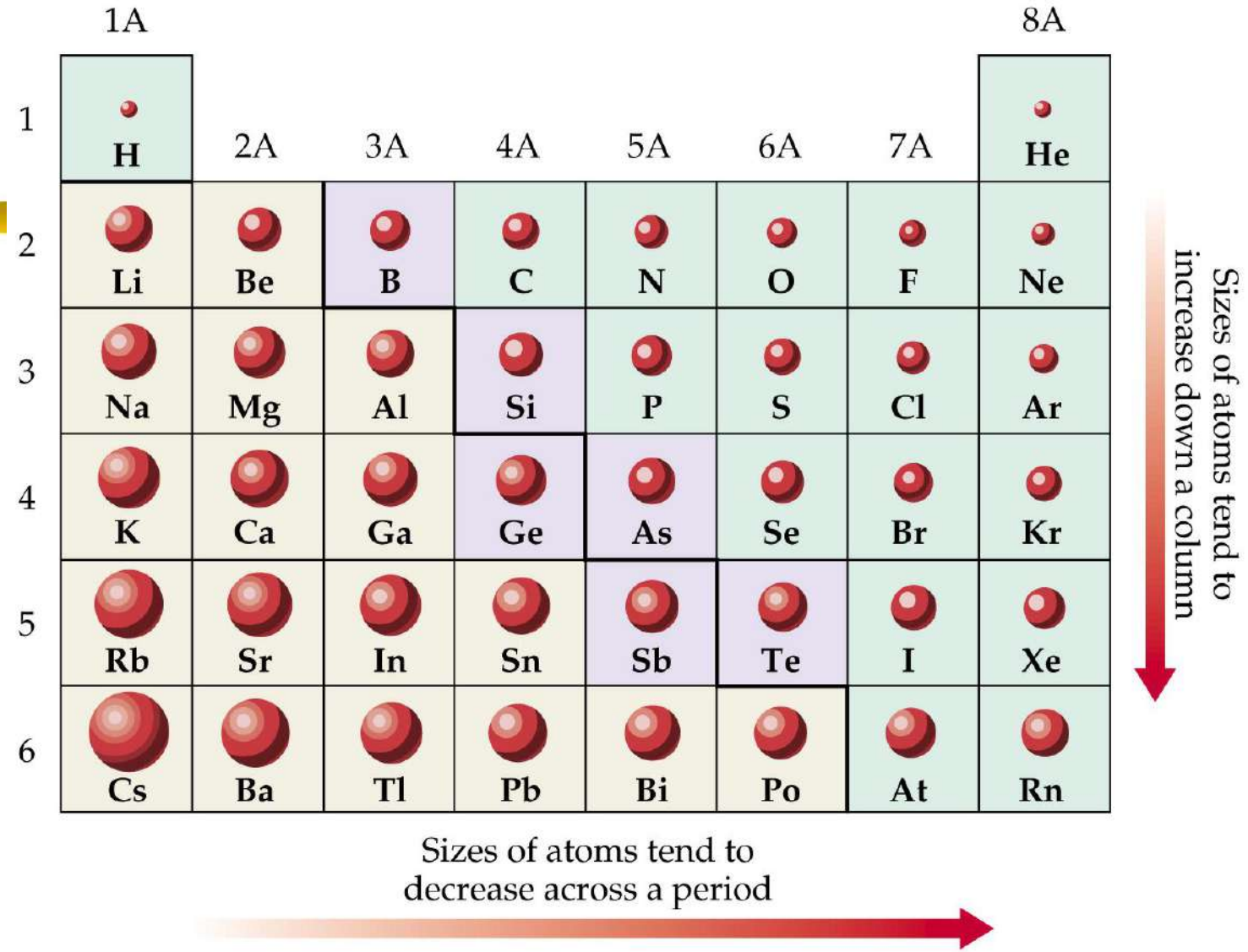
- There are several trends on the periodic table that are based on the position of the elements relative to each other.
- They can be across periods or within families.
  - Group trends are described from top to bottom
  - Period trends are described left to right

Atomic Radius

- The distance from the center of the atomic nucleus to the outermost edge of the electron cloud, measured by taking one half the distance between the nuclei of two atoms of the same element that have been brought as close to each other as possible.



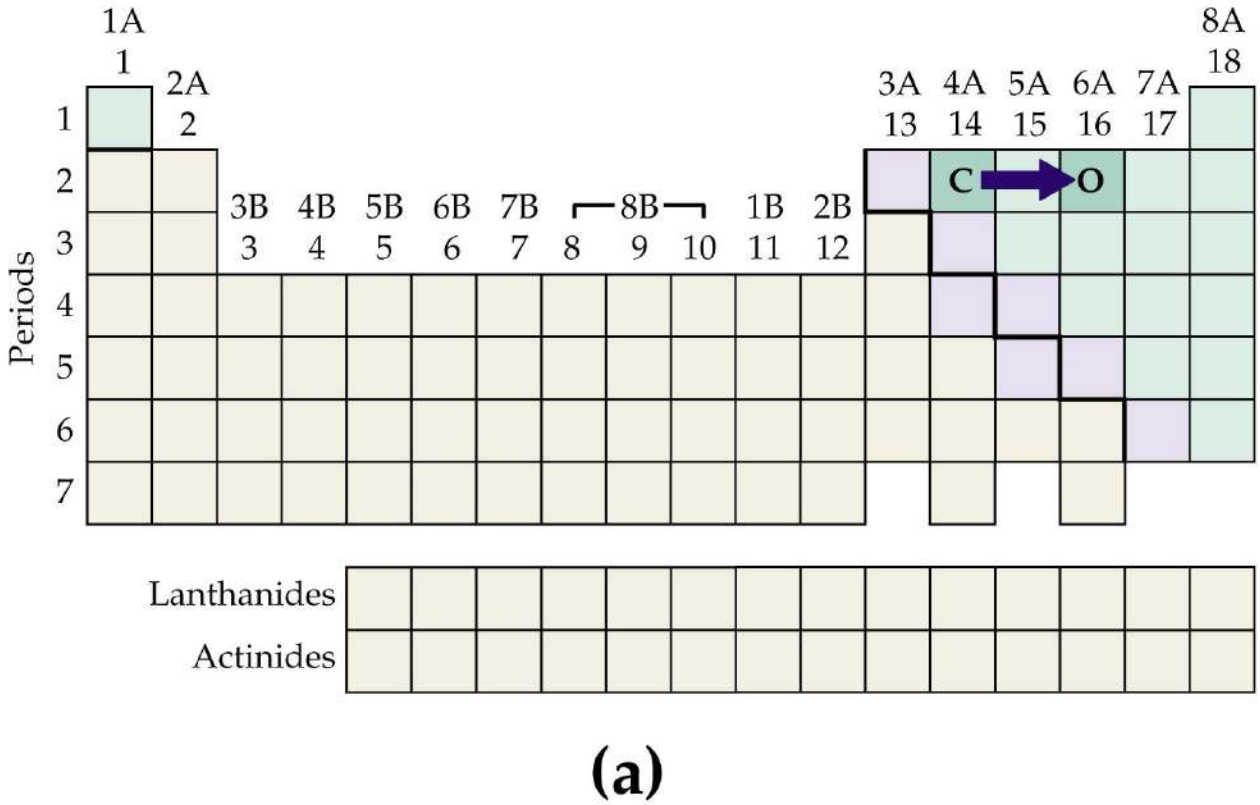
Relative atomic sizes of the representative elements



Atomic radii for the elements ***increase*** as you travel down a group due to the *shielding effect*, since there is an increasing number of electron shells that weaken the attraction between the nucleus and valence electrons.

- Atomic radii for the elements ***decrease*** as you travel left to right across a period due to *increasing Coulombic attraction* between the nucleus and valence electrons as more protons are added without the addition of new energy levels.

Which is larger? Carbon or Oxygen?

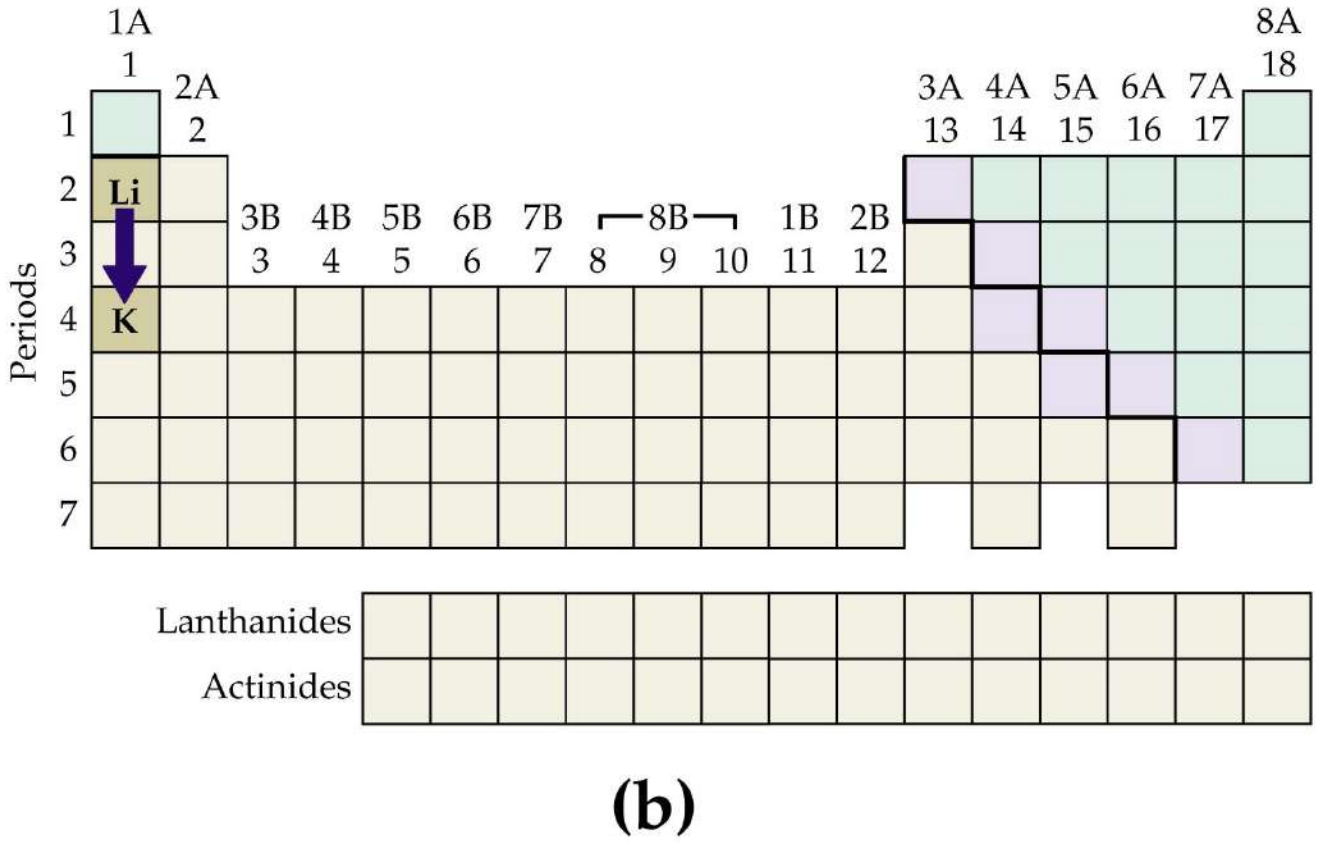


(a)

Answer

- Carbon is larger than oxygen, but why?
- Carbon and oxygen have the same number of energy levels, but oxygen has more protons in the nucleus, hence a greater Coulombic attraction for its valence electrons. So, oxygen is smaller. Carbon is, therefore, larger.

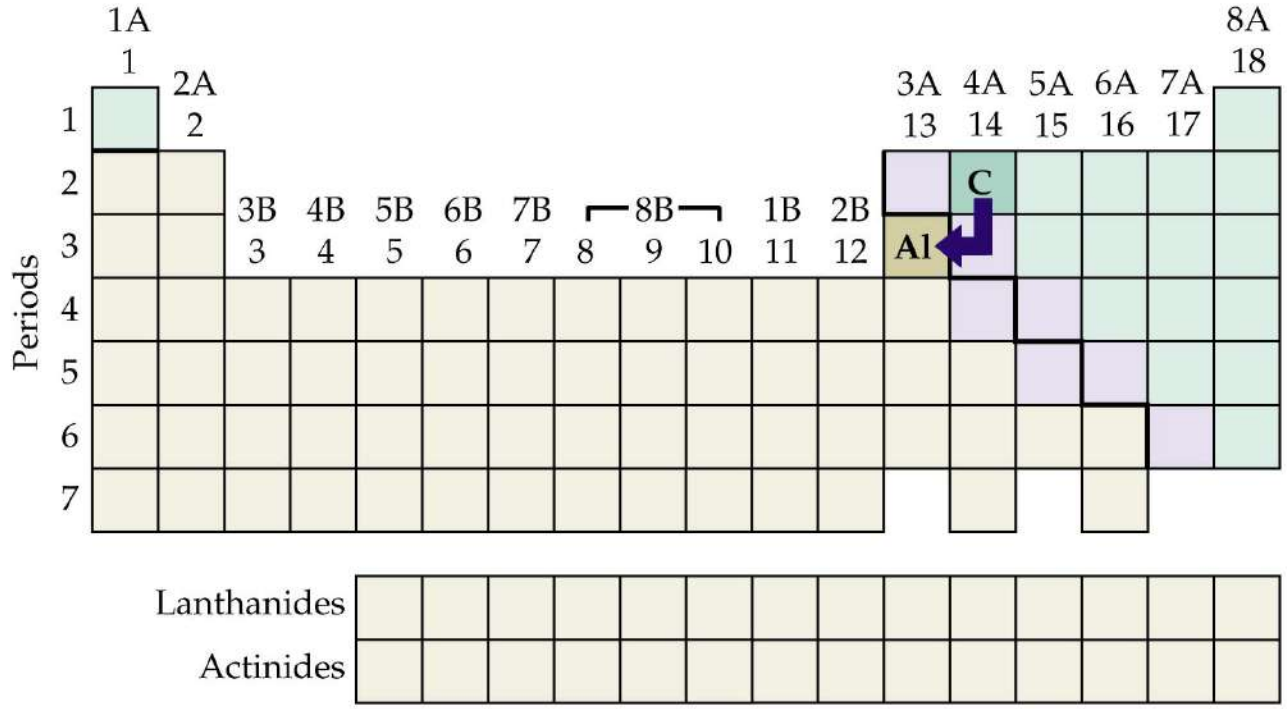
Which is larger? Li or K?



Answer

- Potassium (K) is larger than Lithium (Li).
- Why?
- Potassium has more energy levels than lithium (a greater shielding effect), hence a weaker Coulombic attraction between the nucleus and valence electrons.

Which is larger? C or Al?



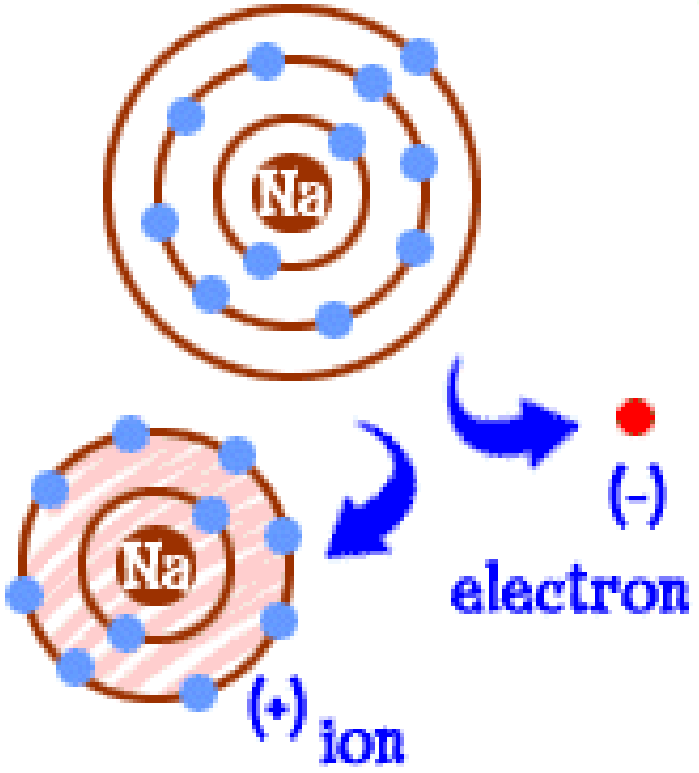
(c)

Answer

- Aluminum (Al) is larger than carbon (C).
- Why?
- Aluminum has more energy levels than carbon, hence it has a weaker Coulombic attraction for its valence electrons (greater shielding effect).

Atomic Radius of Ions

- ***Cations*** are formed by losing electrons.
- The loss of electrons to achieve a stable octet results in the loss of an energy level which strengthens the attractive force of the positive nucleus to its negatively charged valence electrons.
- Hence, ***a cation is always smaller than a neutral atom of the same element*.**



Atomic Radius of Ions

- Anions are formed when atoms gain electrons.
- Gaining electrons, without new protons being added to the nucleus, increases the repulsive forces experienced between valence electrons.
- Hence, ***an anion is always larger than a neutral atom of the same element*.**

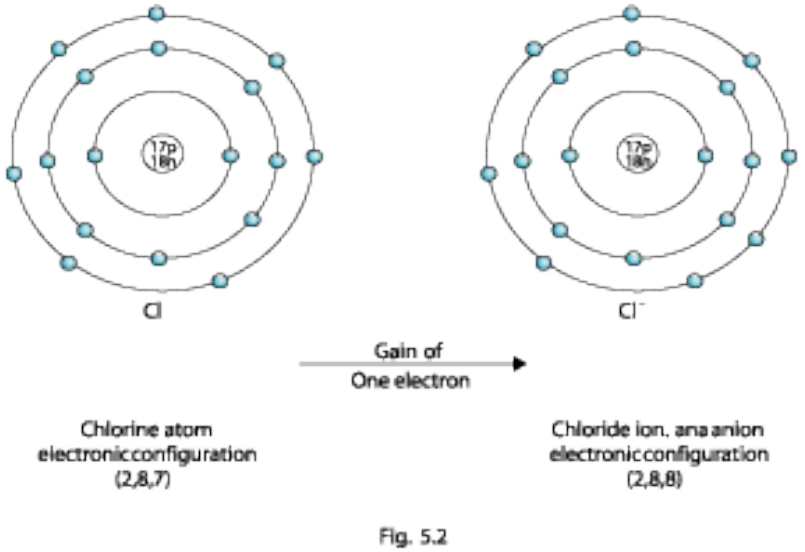


Fig. 5.2

Ionization Energy

- The amount of energy required (must be put into an element) to remove an electron from the outermost energy level (i.e. valence shell) of an atom when it is in the gas phase.

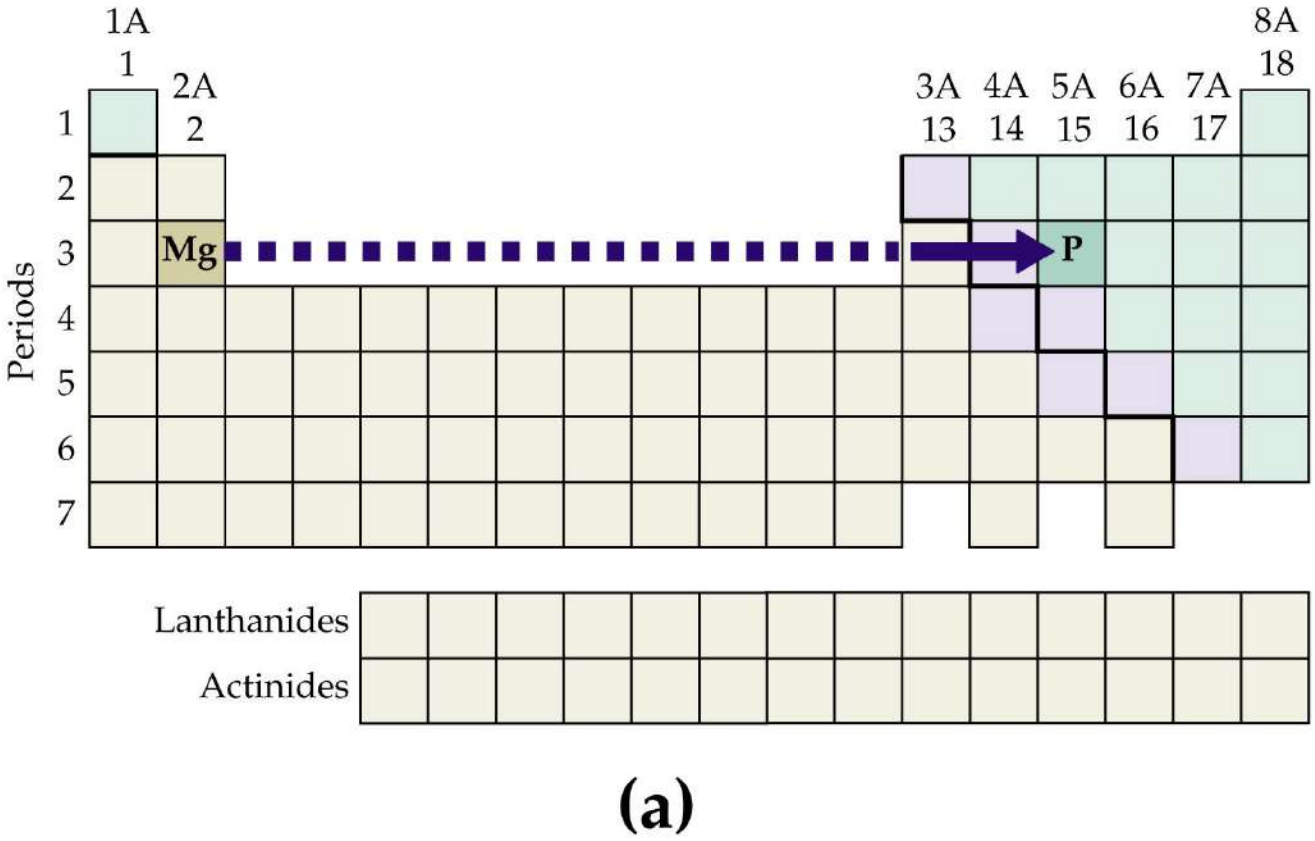
Ionization Energy – Group Trend

- Ionization energies *decrease* down a group due to *shielding effect*. In other words, it takes less energy to remove electrons from the valence shell when the Coulombic attraction between the nucleus and valence electrons is weakened by the addition of new energy levels.

Ionization Energy – Period Trend

- Ionization energies *increase* across a period due to increasing Coulombic attraction. In other words, it takes more energy to remove electrons when the Coulombic attraction between the nucleus and valence electrons is stronger due to the addition of new protons without new energy levels being added.

Which element has the larger ionization energy: Mg or P?

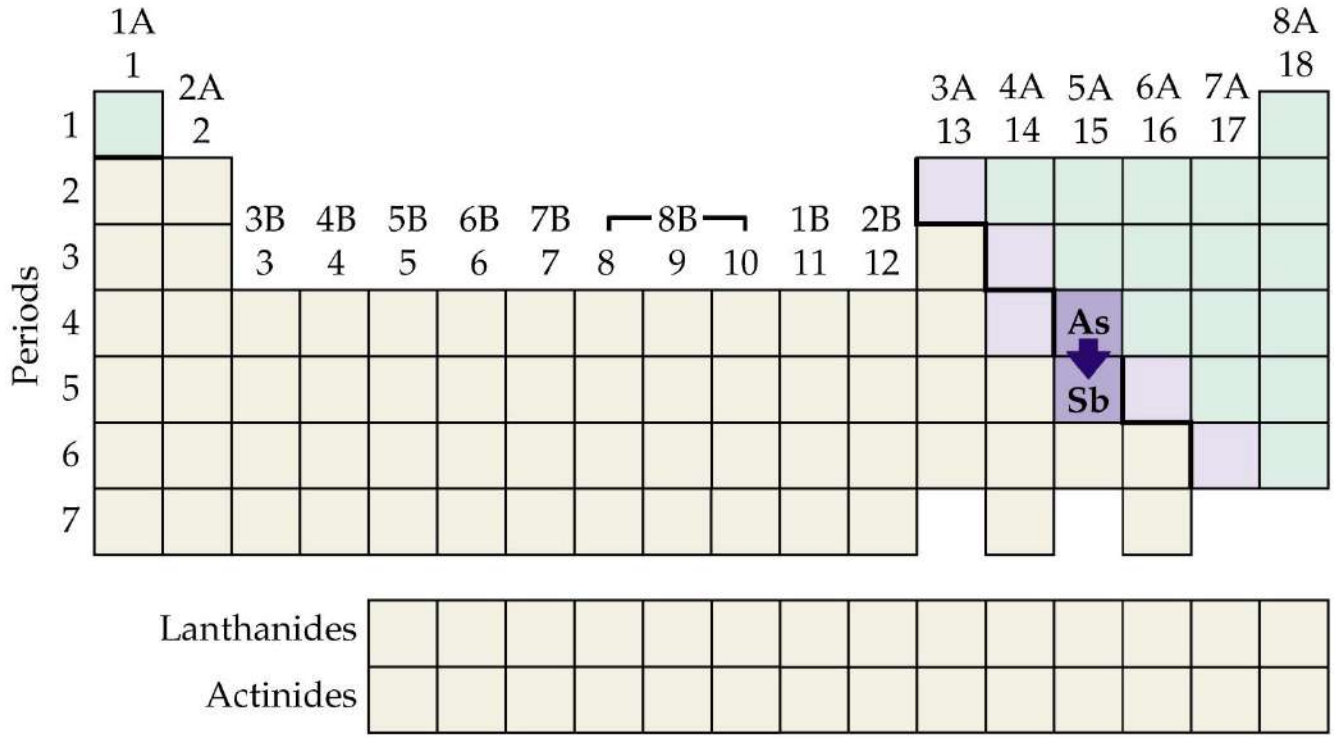


(a)

Answer

- Answer: P has the larger ionization energy, so that means it is more difficult to remove a valence electron from P than Mg. Why?
- P has a stronger Coulombic attraction between its nucleus and valence electrons because it has more protons but the same number of energy levels.

Which element has the larger ionization energy: As or Sb?

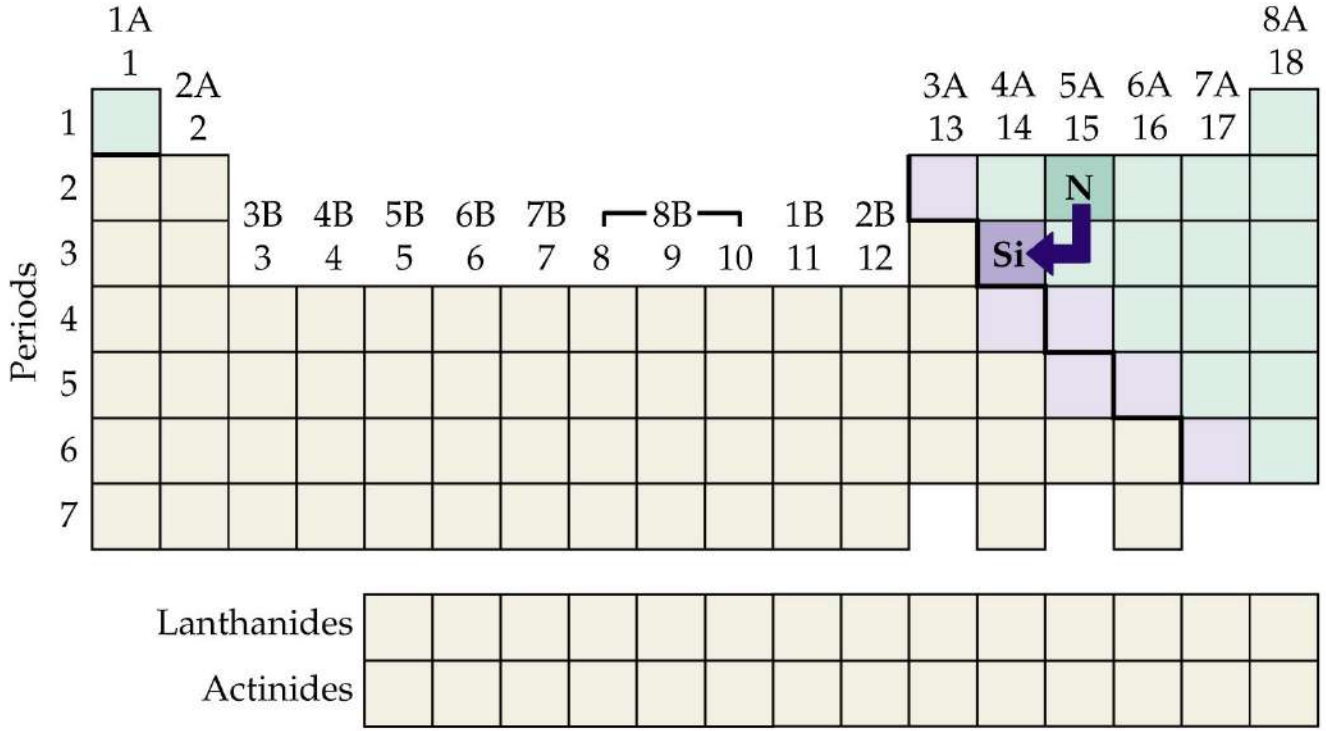


(b)

Answer

- Answer: As has a higher ionization energy than Sb. Why?
- As has a stronger Coulombic attraction for its valence electrons because it has less shells between the nucleus and its valence electrons.
- Sb, with more shells, has a weaker Coulombic attraction and a lower ionization energy.

Which element has the larger ionization energy: N or Si?



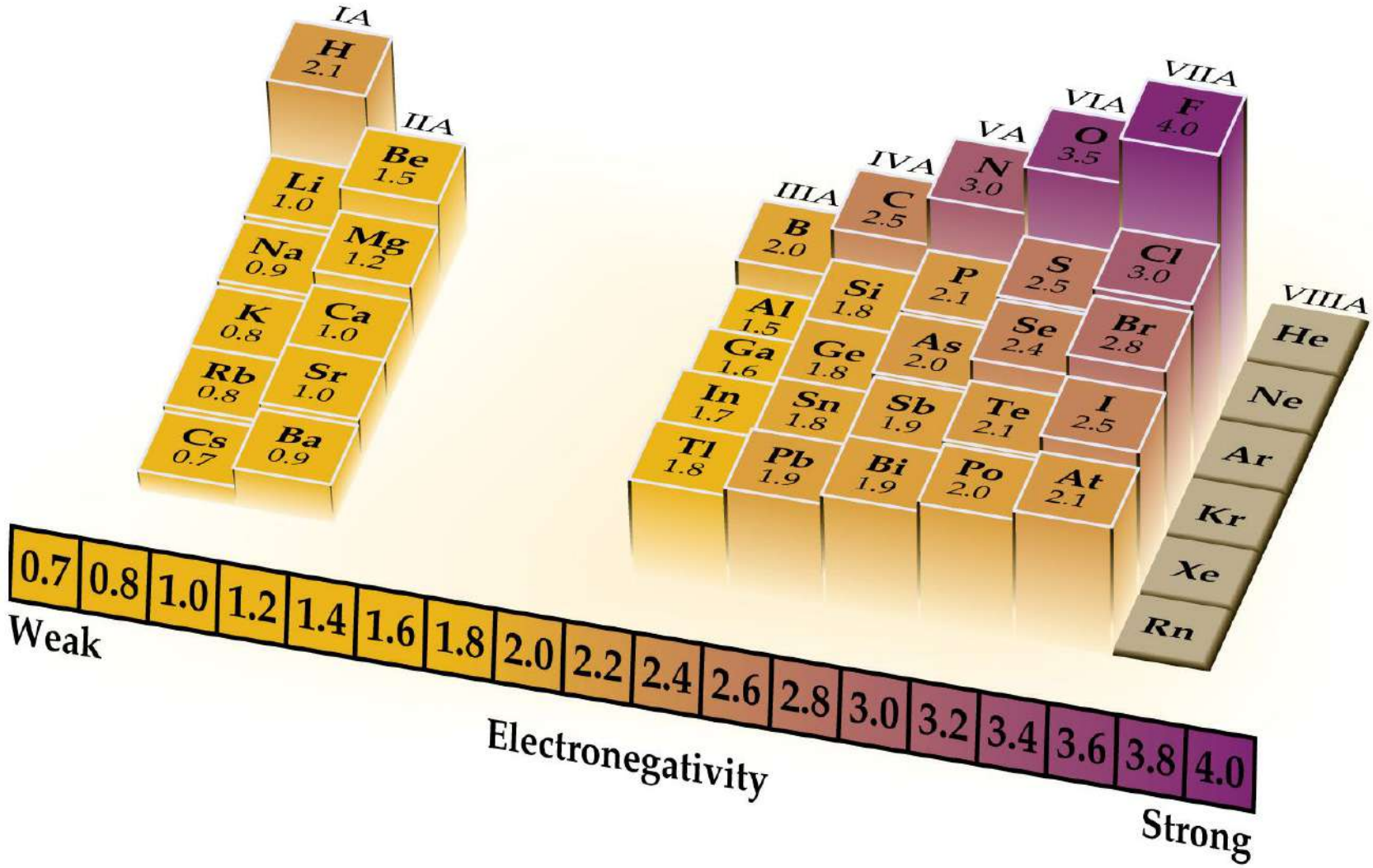
(c)

Answer

- Answer: N has a higher ionization energy than Si.
- Why? N has a stronger Coulombic attraction for its valence electrons because it has fewer shells separating the nucleus from its valence electrons.
- Si, with more shells, has a weaker Coulombic attraction and a lower ionization energy.

Electronegativity

- The tendency of an atom to attract electrons to itself in a chemical bond.
- All electronegativity values (0 - 4) are measured and assigned with respect to the most electronegative element of the periodic table - Fluorine (F = 4).
- Noble gases rarely have electronegativity values reported because they do not naturally form chemical bonds with other elements.


IA
IIA
IIIA
IVA
VA
VIA
VIIA
VIIIA
H 2.1
Be 1.5
Li 1.0
Mg 1.2
Na 0.9
Ca 1.0
K 0.8
Sr 1.0
Rb 0.8
Ba 0.9
Cs 0.7
B 2.0
C 2.5
N 3.0
O 3.5
F 4.0
Al 1.5
Si 1.8
P 2.1
S 2.5
Cl 3.0
Ga 1.6
Ge 1.8
As 2.0
Se 2.4
Br 2.8
In 1.7
Sn 1.8
Sb 1.9
Te 2.1
I 2.5
Tl 1.8
Pb 1.9
Bi 1.9
Po 2.0
At 2.1
He
Ne
Ar
Kr
Xe
Rn
0.7 0.8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0
Weak
Electronegativity
Strong

Electronegativity – Group Trend

- Electronegativity values *decrease* down a group due to the shielding effect.
- The ability of an atom to attract electrons to itself *decreases* as the number of energy levels separating the nucleus from the valence shell *increases*.

Electronegativity – Period Trend

- **Electronegativity values** *increase* across a period due to increasing Coulombic attraction.
- As the number of protons in the nucleus *increases* without the addition of new energy levels, the ability to attract electrons *increases*.

Practice

- Compare electronegativity of the following elements – which is more electronegative?
  1. Calcium, nitrogen
  2. Fluorine, bromine
  3. Silicon, sulfur
  4. Oxygen, phosphorous
  5. Oxygen, Fluorine

Answers

1. *Nitrogen* – fewer shells, stronger Coulombic attraction
2. *Fluorine* – fewer shells, stronger Coulombic attraction
3. *Sulfur* – more protons in the nucleus, stronger Coulombic attraction
4. *Oxygen* – fewer shells, stronger Coulombic attraction
5. *Fluorine* – more protons in the nucleus, stronger Coulombic attraction

Reactivity

- The ability of an atom to gain, lose, or share electrons with another element to form a compound.
- Metals and non-metals show opposite reactivity trends.

- Metals:
  - Metals react by *losing electrons*
  - Group trend: *Increases* as you move down a group due to the shielding effect.
  - Period trend: *Decreases* across a period due to stronger Coulombic attraction

- Non-metals:
  - Non-metals react by *gaining electrons*.
  - Group trend: *Decreases* down a group due to the shielding effect.
  - Period trend: *Increases* across a period due to stronger Coulombic attraction.