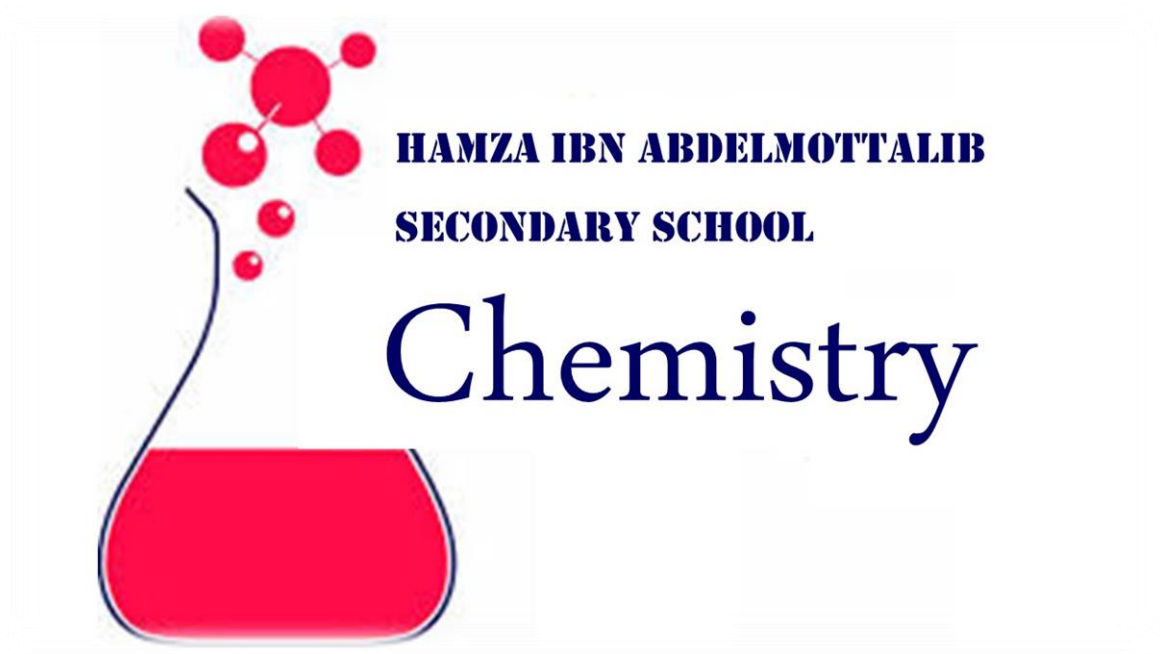
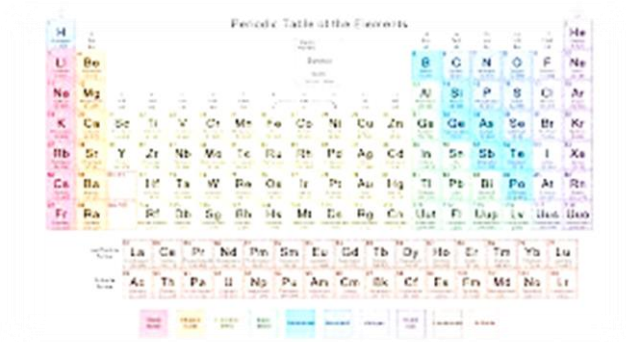



# Periodic table

2019/2018



# Development of the Modern Periodic Table

**Introduction**

MOHAMED
Ahmed Abdelbari

**Atom**: *the smallest, indivisible unit of an element that retains all chemical and physical properties of the element.*

For example, a single atom of gold has the same physical and chemical properties as 10 tons of gold. Atoms are composed of three **subatomic particles**.

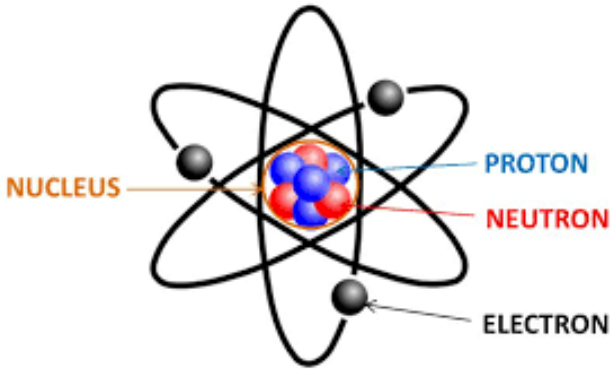
**subatomic particles**: protons, neutrons, and electrons.

## The Atom consists of:

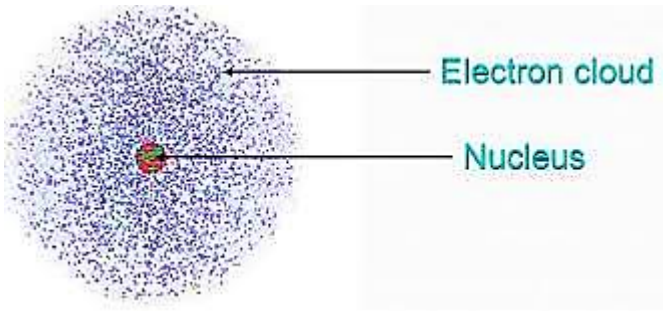
1) **The nucleus**: *A high-density region that is present in the center of the atom and contains protons of neutrons*

a) **Protons**: *particles that carry a positive electrical charge and are present within the nucleus of the atom*

b) **Neutrons**: *particles that do not carry an electrical charge and are present inside the nucleus of the atom*




2) **Electrons**: *particles that carry a negative charge and are found outside the nucleus*




**Electron cloud**: *The region where the electrons are located around the nucleus.*

Protons and electrons have opposite charges and the number of protons in any atom is equal to the number of electrons, **so the atom is electrically neutral**.

## Different atoms of elements:

All the elements in nature are made up of atoms. The atoms of elements differ from one another in the number of protons, neutrons and electrons

**Atomic number**: *The number of protons in the nucleus of the atom of the element*.

The nucleus of the hydrogen atom has 1 proton, so the atomic number of hydrogen is 1, In the nucleus of the oxygen atom there are 8 protons so the atomic number of oxygen is 8

**Mass number**: *The total number of protons and neutrons in the nucleus of the atom*.

Electrons do not enter in the calculation of the mass number because the mass is too small and can be neglected.

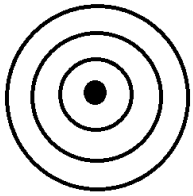
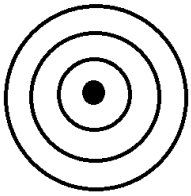
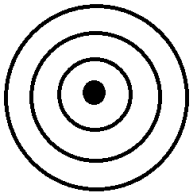
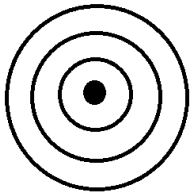
*1) Classify the next materials (Element, Compound)*

| matter | kind | matter | Kind |
|---|---|---|---|
| Carbon dioxide | | Sodium | |
| Hydrogen | | Sulfur oxide III | |
| Sodium bicarbonate | | Potassium | |
| Zink sulfate | | Oxygen | |
| Helium | | Hydrochloric acid | |
| Iron chloride III | | Aluminum | |
| Carbon | | Ammonium Nitrate | |

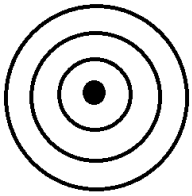
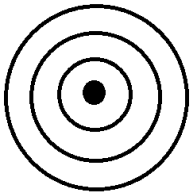
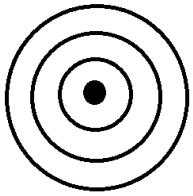
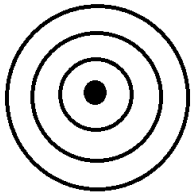
*2) Complete the next Table*

| Element | Atomic no. | Atomic mass | # protons | # Electrons | # neutrons |
|---|---|---|---|---|---|
| $^{3}_{7}Li$ | | | | | |
| $^{8}_{16}O$ | | | | | |
| $^{17}_{35}Cl$ | | | | | |
| $^{47}_{108}Ag$ | | | | | |
| $^{10}_{20}Ne$ | | | | | |
| $^{9}_{19}F$ | | | | | |

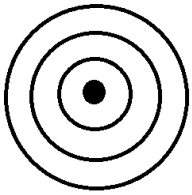
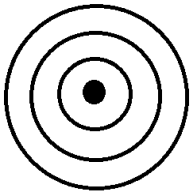
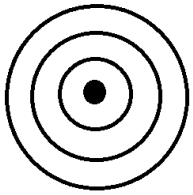
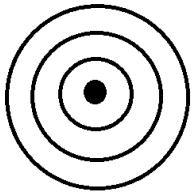
*3) Complete the Electron configuration of each element:*

| Element | $^{3}_{7}Li$ | $^{4}_{9}Be$ | $^{5}_{11}B$ | $^{6}_{12}C$ |
|---|---|---|---|---|
| # Electrons | | | | |
| electron configuration |  |  |  |  |
| | 2 , 1 | | | |
| # Valence electrons | | | | |

*4)*

| Element | $^{11}_{23}Na$ | $^{13}_{27}Al$ | $^{17}_{35}Cl$ | $^{18}_{40}Ar$ |
|---|---|---|---|---|
| # Electrons | | | | |
| electron configuration |  |  |  |  |
| | | | | |
| # Valence electrons | | | | |

*5)*

| Element | $^{1}_{1}H$ | $^{20}_{40}Ca$ | $^{34}_{79}Se$ | $^{35}_{80}Br$ |
|---|---|---|---|---|
| # Electrons | | | | |
| electron configuration |  |  |  |  |
| | | | | |
| # Valence electrons | | | | |

# Periodic table

**Scientists tried to organize elements in a table,**

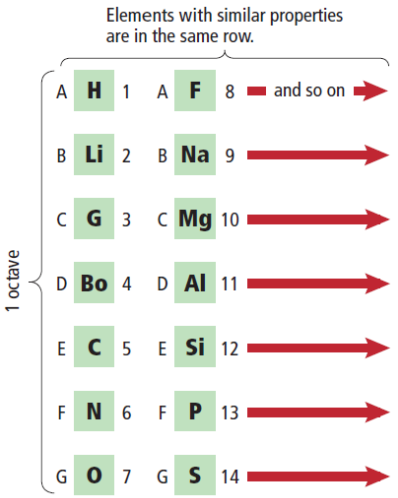
## Lavoisier

He organized elements in four categories Gases, Metals, Nonmetals, and Earths.

**Lavoisier's Table of Simple Substances**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Metals** | **Antimony** | **Copper** | **Silver** | **Iron** | **Arsenic** | **Manganese** | **Bismuth** | **Tungsten** | **Platina** |
| | **Cobalt** | **Tin** | **Mercury** | **Lead** | **Molybdena** | **Nickel** | **Gold** | **Zinc** | |
| **Nonmetals** | **Sulphur** | **Phosphorus** | **Pure charcoal** | **Radical boracique** | | **Radical muriatique** | | **Radical fluorique** | |
| **Earths** | **Chalk, calcareous earth** | | **Magnesia, base of Epsom salt** | | **Barote, or heavy earth** | **Clay, earth of alum, base of alum** | | **Siliceous earth, verifiable earth** | |
| **Gases** | **Light** | **Heat** | **Dephlogisticated air** | | **Phlogisticated gas** | | **Inflammable air or gas** | | |

## John Newlands' Octaves



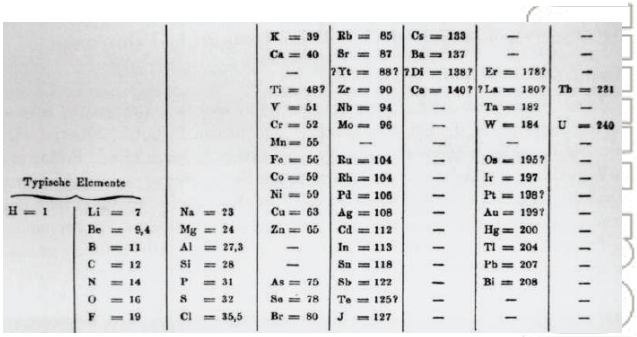
Newlands wanted to relate all the elements to each other. Newlands arranged the known elements in a table by **atomic weights**.

In doing so, he noticed some recurring patterns, and the patterns were such that if he broke up his list of elements into groups of seven, the first elements in each of those groups were similar to one another, as was the second element in each group, and the third, and so on. By analogy with the tonic musical scale of seven notes, which form octaves, he called his discovery the **Law of Octaves**

## Meyer and Dmitri Mendeleev

Mendeleev arranged the elements in a table ordered by **atomic mass**.

In large part, the success of the Mendeleev's analysis can be attributed to the gaps which he predicted would contain undiscovered elements with predictable properties.



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

## Henry Moseley

Mosley's research demonstrated that the **ordering of elements in the table should be according to atomic number not atomic weight**.

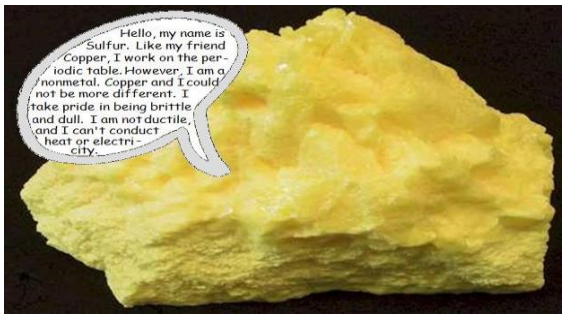
**PERIODIC LAW:** The Periodic Law States That when elements are arranged in order of increasing atomic number, there is a periodic repetition of their physical and chemical properties.

# Periods and Groups

Elements in the periodic table are arranged in periods (rows) and groups (columns). Atomic number increases as you move across a period.

## Metals

Metals are located on the left side of the periodic staircase on the periodic table. They are malleable, ductile, good conductors of heat and electricity, solid at room temperature (except for Mercury), and they have a high luster (they are shiny). Metals make up most of the elements in the periodic table.


## Nonmetals

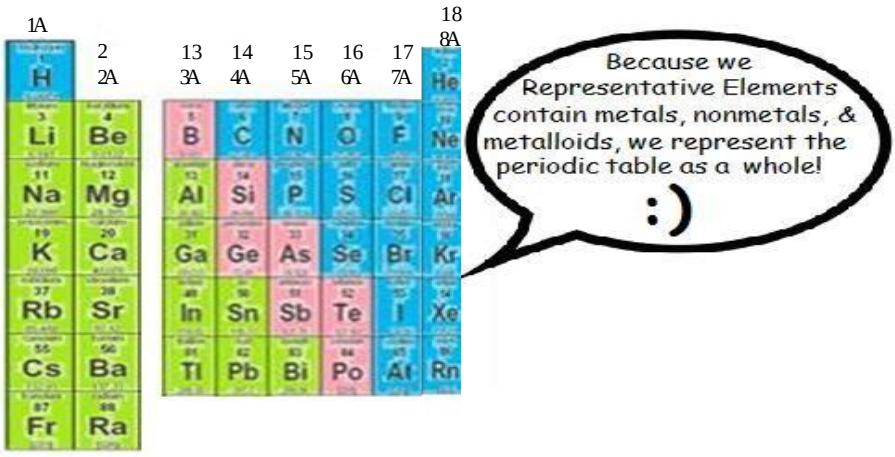
Nonmetals are located on the right side of the periodic staircase on the periodic table (except for Hydrogen). They are brittle, not ductile, poor conductors of heat and electricity, and they have a low luster. Most are gases at room temperature, but some are solids and Bromine is a liquid.

## Metalloids

Metalloids have properties of both metals and nonmetals. A metalloid may behave as a metal under some conditions, but the same metalloid may behave as a nonmetal under other conditions.


## Representative Elements

The representative elements are found in groups 1 through 2 and groups 13 through 18 on the periodic table.



## Transition metals

The transition metals are groups 3 through 12 in the middle of the periodic table

## Inner transition metals

The inner transition metals are found underneath the periodic table. The **Lanthanide** series belongs in period 6 and the **Actinide** series belongs in period 7.

6) ***Label the following elements as a metal, nonmetal, or metalloid***

| Element | Classification | Element | Classification | Element | Classification |
|---|---|---|---|---|---|
| C | | Pd | | Xe | |
| Mg | | H | | Si | |
| Bi | | Es | | O | |
| Na | | Ne | | B | |

7) ***Circle the following element that is a metalloid***

Argon Germanium Bismuth Zinc Hydrogen

8) ***Circle the following element that is not a transition metal***

Osmium Titanium Gold Radon Copper

9) ***Circle all of the following elements that are representative elements***

Sulfur Cerium Sodium Aluminum Iron

10) ***Circle the following element that is an inner transition metal***

Nitrogen Hassium Californium Mercury Lithium

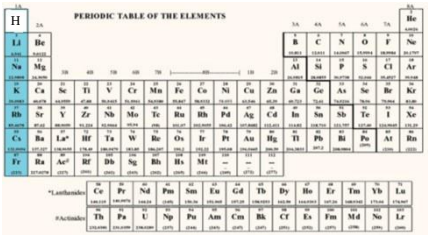
11) ***Complete the following:***

- There are _____ groups and _____ periods in the periodic table.
- Chlorine has _____ valence electrons
- Groups 3 – 12 are called the __ ___ metals.
- Write the symbol of the element that is in the 3rd period and group 13 ____ _____
- Write the symbol of the element that is in the 5th period and group 11 ____ _____

## Important Groups

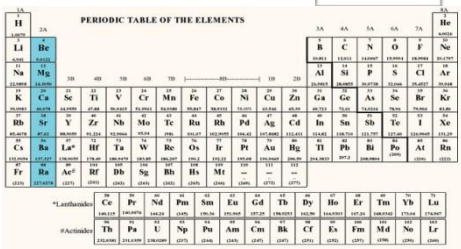
Elements in a group share similar chemical and physical properties. There are groups of elements in the periodic table that are given special names.

### Alkali Metals (Li, Na, K, Rb, Cs, Fr)



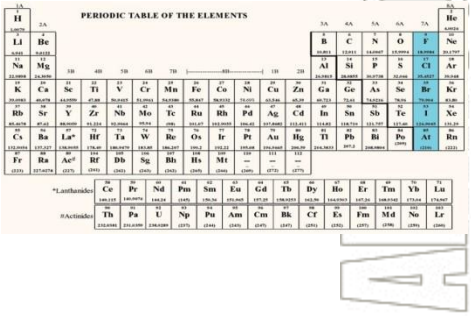

- ✓ Alkali metals, excluding Hydrogen, are found in Group 1.
- ✓ They only have **one valence electron** in their outermost energy.
- ✓ Only having one valence electron leads to alkali metals being **very unstable and highly reactive**, meaning it is likely to bond with other elements and lose its 1 valence electron.
- ✓ They are all **metals, extremely soft metals, which can be cut with a butter knife**.
- ✓ Alkali metals are **very abundant in nature**.
- ✓ they **have low densities and low melting and boiling points**.

### Alkaline Earth Metals (Be, Mg, Ca, Sr, Ba, Ra)



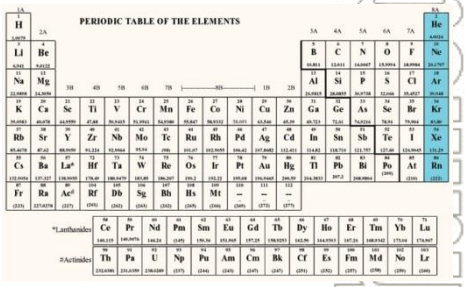

- ✓ Alkaline earth metals are found in **Group 2**.
- ✓ They have **two valence electrons** and **very reactive**, likely to bond with other elements and lose 2 electrons.
- ✓ All the elements in the group bond similarly and there for have similar properties.

### Halogens (F, Cl, Br, I, At)



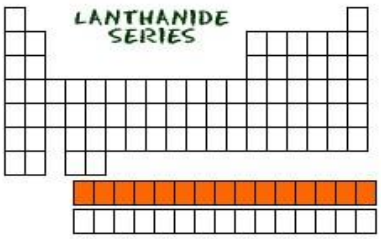

- ✓ Halogens are found in **Group 17**.
- ✓ They **have seven valence electrons**, so want to gain 1 more electron to make their outer energy level full.
- ✓ A halogen will **easily bond with an alkali metal** (whom wants to lose 1 $e^-$), together they form a salt. Example NaCl (sodium chloride) is table salt.

### Noble Gasses (He, Ne, Ar, Kr, Xe, Rn)



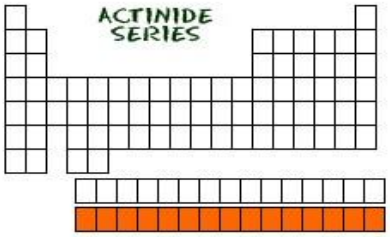

- ✓ Noble gasses are found in **Group 18**.
- ✓ They have **eight valence electrons** and are the **most stable** of the elements (**non-reactive**).
- ✓ Their outermost energy level or shell is full, so they do **not naturally bond with other elements**.
- ✓ Noble gasses share properties like **high densities, high melting points, colorless, odorless, and tasteless**.

## Lanthanide Series




- ✓ The lanthanide series include the **"rare-earth elements"** and are found on the top row of the inner transition metals.
- ✓ These elements are **part of period 6**.
- ✓ The lanthanide series get it name from the element **Lanthanum** (La) atomic number 57 where the row would fall after.
- ✓ All the elements in the lanthanide series have common properties to the element Lanthanum.

## Actinide Series




- ✓ The actinide series includes all **radioactive metals** and can be found on the bottom row of the inner transition metals.
- ✓ These elements are **part of period 7**.
- ✓ The actinide series is named after the element **Actinium** (Ac) atomic number 89 where the row would fall after.
- ✓ All the elements in the lanthanide series have common properties to the element Actinium.

## Locating an Element in periodic table

The location of the element in the periodic table depends on the number of protons. The period can be deduced by the number of valence electrons. The number of electrons at the outer level of any atom ranges between (1) and (8). The probability of the presence of the element in the table is as follows:

| | **# Valence electrons** | |
|---|---|---|
| | **(1 one) or (2)** | **(three) to (8 eight)** |
| Method of calculating the group number | The same number of electrons of the last level | Add 10 to the number of electrons at the outer level |
| Example | Lithium $^{3}_{7}Li$<br>• Electronic config : 2,1<br>• # Valence electrons :1<br>• The element exists in group: 1 | chlorine $^{17}_{35}Cl$<br>• Electronic config: 2,8,7<br>• # Valence electrons: 7<br>The element exists in group:17 |

## Classification of elements: s-, p-, d-, f- Blocks

**_s_-Block Elements**

The elements of group 1 (alkali metals) and group 2 (alkaline earth metals) belong to the ***s*-block elements.**

***p*-Block Elements**

The ***p*-Block Elements** comprise those belonging to groups 13 to 18**.**

**Representative Elements or Main Group Elements:** The p-Block Elements together with the s-block elements

**The *d*-block Elements (Transition Elements)**

These are the elements of group 3 to 12 in the center of the periodic table

**The *f*-Block Elements (Inner-Transition elements)**

The two rows of elements at the bottom of the periodic table, called the **Lanthanoids** and **Actinoids.**

***12) Use the following words to match up to the descriptions below.***

**Representative Elements Transition Metals Inner Transition Metals Periods Groups Lanthanide Series Actinide Series Metals Metalloids Non-metals Alkali Metals Alkaline Earth Metals Halogens Noble Gases**

a) _____ all elements in this series are radioactive

b) _____ poor conductors of heat& electricity; solids are dull & brittle

c) _____ made up of groups 1,2, & 13---18

d) _____ vertical columns on the periodic table; all elements have similar chemical & physical properties; all elements have the same number of valence electrons

e) _____ The p-Block Elements together with the s-block elements

f) _____ made up of the Lanthanide series and the Actinide series

g) _____ do not naturally combine with other elements

h) _____ are ductile, malleable and lustrous

i) _____ all elements of this group have 2 valence electrons

j) _____ made up of groups 3---12

k) _____ elements in this group easily bond with an alkali metal to form a salt.

l) _____ the "Rare Earths Elements"

m) _____ horizontal rows, atomic number increases as you move across the row

n) _____ all elements in this group have 1 valence electron

o) _____ have the properties of both metals & non-metals

| | | | |
|---|---|---|---|
| _____ | Nitrogen | _____ | Radon |
| _____ | Uranium | _____ | Rubidium |
| _____ | Silver | _____ | Radium |
| _____ | Bromine | _____ | Calcium |
| _____ | Lithium | _____ | Sulfur |
| _____ | Iodine | _____ | Lead |
| _____ | Neon | _____ | Bismuth |
| _____ | Silicon | _____ | Antimony |

***13) Write the suitable answer beside the following,***

1) _____ Transition Metal number 24
2) _____ A common solid halogen
3) _____ Family 13 bears this name
4) _____ An active alkaline earth metal with 56 protons
5) _____ The alkali metal of period 3
6) _____ ____ The metal element that makes up table salt
7) _____ The first of the alkali metals
8) _____ The first element of family 16
9) _____ A period 2 nonmetal with 5 valence electrons
10) _____ Element with atomic number 31
11) _____ The last of the alkaline earth metals
12) _____ Mendeleev predicted the existence of this metalloid
13) _____ The first element in the actinide series
14) _____ Period 2 nonmetal with 6 valence electrons
15) _____ The last of the noble gases
16) _____ A transition metal used in incandescent light bulbs.
17) _____ Period 4, Group 15 element
18) _____ The second element in Group 15
19) _____ Period 3 element with 6 valence electrons.
20) _____ This element is in the same family as lead and it has fewer protons than sodium.
21) _____ This element has an atomic number that is one greater than platinum.
22) _____ This element has the most protons of any element in group 15.
23) _____ This element has the more than 50 but less than 75 protons and it is in group 17.
24) _____ This group 2 element has fewer protons than bromine, but more protons than sulfur.
25) _____ This element has the lowest atomic number of any group 16 element.

26) _____ This element has an atomic number that is double the atomic number of silicon.

27) _____ This element has more valence electrons than oxygen, fewer valence electrons than neon, more protons than sodium, but fewer protons than argon.

28) _____ This element has an atomic number lower than that of aluminum and one less valence electron than the group 16 elements.

29) _____ This element is in group 1 and has a high atomic number than chlorine, but a lower atomic number than bromine.

30) _____ Which element is a metal: Ba or At ?

31) _____ Which period is Ca in ?

32) _____ What is the number of the group N is in ?

33) _____ Which element is an alkali metal: Rb or Al ?

34) _____ Which element is a halogen: Na or Cl ?

35) _____ Which element is a noble gas: Ne or Br or O ?

36) _____ Which element would be a positive ion in a compound: Sr or Te ?

37) _____ How many electron dots should As have ?

38) _____ Which element has 5 valence electrons? B or P ?

39) _____ Which element has 18 electrons ?

40) _____ How many neutrons does bromine-80 have?

***14) On the line to the right identify the element's family if it belongs to one of the families listed below, otherwise leave the line blank.***

**Metals - Alkali Metal - Halogen - Nonmetals - Group 2 Metal**
**Noble gas - Metalloids - Transition Metal**

| | | | | | |
|---|---|---|---|---|---|
| _____ | Potassium | _____ | Magnesium | _____ | Germanium |
| _____ | Sulfur | _____ | Gold | _____ | Fluorine |
| _____ | Antimony | _____ | Krypton | _____ | Cesium |
| _____ | Iodine | _____ | Bromine | _____ | Titanium |

***15) Which one of the following pairs of elements is the most metallic?***

1. _____ a) potassium b) bromine
2. _____ a) cesium b) sodium
3. _____ a) silicon b) aluminum
4. _____ a) gold b) bismuth

***16) Two elements X and Y have the following properties.***

| Element X | Element Y |
|---|---|
| Metallic luster<br>Two valence electrons<br>Located in the 4th period | Without metallic luster<br>Four valence electrons<br>6 protons |

1. Which symbols from the periodic table correspond to elements X and Y respectively?
   A) Ca and C B) K and B C) K and C D) Ca and B

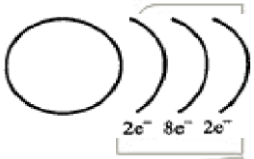
2. Which of the following statements about the properties of metals is correct? A) They are ductile but are not shiny.
   B) They conduct electricity but are not ductile.
   C) They do not conduct electricity and are not shiny.
   D) They conduct electricity and heat and are opaque.

***17) Four elements from the periodic table are described below.***

***Element A****: This metal reacts vigorously with water and its electrons are distributed among three energy levels.*

***Element B:*** *This nonmetal is located in Period 3 and used to disinfect or to kill bacteria in pools.*

***Element C****: Its electron configuration is pictured in the Bohr model to the right*



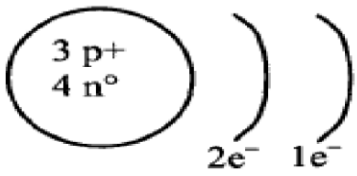

***Element D***: Its outermost energy level is full and it could have 22 neutrons.

*Complete the table by indicating the symbol and the name of the chemical family for each of these elements.*

| Element Chemical | Symbol Chemical | Family Name | Block |
|---|---|---|---|
| Element A | | | |
| Element B | | | |
| Element C | | | |
| Element D | | | |

***18) The following diagram represents the Bohr model of an element.***

1. Which of the following is true?
   a) The element is located in period 1 and is a Group II Metal
   b) The element is located in period 1 and is an alkali metal.
   c) The element is located in period 2 and is an alkali metal.
   d) The element is located in period 2 and is a halogen



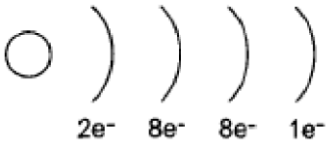

***19) Which of the following states two properties of the elements in the halogen family?***
   a) They are soft metals and highly reactive.
   b) They do not conduct electricity and are not shiny.
   c) They conduct electricity but are less reactive than alkali metals.
   d) They are colorless in their natural state and are not chemically reactive

***20) An element has the following characteristics:***
- *It has a metallic luster.*
- *It conducts electricity.*
- *It has 3 valence electrons.*
- *It is a metal.*
-

***What is this element?***

A) Aluminum B) Lithium C) Silicon D) Sodium

***21) The following diagram represents the Bohr atomic model for an element in the periodic table.***




***22) Which of the following is a correct statement about this element?***
   A) It is an alkali metal that has 19 protons and is located in Period 4.
   B) It is a nonmetal that is not very reactive and that has 19 protons and 1 valence electron.
   C) It is a halogen that has 19 electrons and is located in Period 1.
   D) It is a highly reactive metal that has 20 protons.

***23) Complete the following.***

| Element | Electron config. | # Valence Electrons | Group | # Energy levels | Period | Block |
|---|---|---|---|---|---|---|
| $^{10}_{20}Ne$ | | | | | | |
| $^{20}_{40}Ca$ | | | | | | |
| $^{1}_{1}H$ | | | | | | |
| $^{4}_{9}Be$ | | | | | | |
| $^{13}_{27}Al$ | | | | | | |
| $^{9}_{18}F$ | | | | | | |
| $^{8}_{16}O$ | | | | | | |
| $^{12}_{24}Mg$ | | | | | | |
| $^{7}_{15}N$ | | | | | | |
| $^{6}_{12}C$ | | | | | | |
| $^{2}_{4}He$ | | | | | | |

# Periodic Table of the Elements

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H Hydrogen 1.01 | | | | | | | | | | | | | | | | | 2 He Helium 4.00 |
| 3 Li Lithium 6.94 | 4 Be Beryllium 9.01 | | | | | | | | | | | 5 B Boron 10.81 | 6 C Carbon 12.01 | 7 N Nitrogen 14.01 | 8 O Oxygen 16.00 | 9 F Fluorine 19.00 | 10 Ne Neon 20.18 |
| 11 Na Sodium 22.99 | 12 Mg Magnesium 24.31 | | | | | | | | | | | 13 Al Aluminum 26.98 | 14 Si Silicon 28.09 | 15 P Phosphorus 30.97 | 16 S Sulfur 32.06 | 17 Cl Chlorine 35.45 | 18 Ar Argon 39.95 |
| 19 K Potassium 39.10 | 20 Ca Calcium 40.08 | 21 Sc Scandium 44.96 | 22 Ti Titanium 47.88 | 23 V Vanadium 50.94 | 24 Cr Chromium 51.99 | 25 Mn Manganese 54.94 | 26 Fe Iron 55.93 | 27 Co Cobalt 58.93 | 28 Ni Nickel 58.69 | 29 Cu Copper 63.55 | 30 Zn Zinc 65.39 | 31 Ga Gallium 69.73 | 32 Ge Germanium 72.61 | 33 As Arsenic 74.92 | 34 Se Selenium 78.09 | 35 Br Bromine 79.90 | 36 Kr Krypton 84.80 |
| 37 Rb Rubidium 84.49 | 38 Sr Strontium 87.62 | 39 Y Yttrium 88.91 | 40 Zr Zirconium 91.22 | 41 Nb Niobium 92.91 | 42 Mo Molybdenum 95.94 | 43 Tc Technetium 98.91 | 44 Ru Ruthenium 101.07 | 45 Rh Rhodium 102.91 | 46 Pd Palladium 106.42 | 47 Ag Silver 107.87 | 48 Cd Cadmium 112.41 | 49 In Indium 114.82 | 50 Sn Tin 118.71 | 51 Sb Antimony 121.76 | 52 Te Tellurium 127.6 | 53 I Iodine 126.90 | 54 Xe Xenon 131.29 |
| 55 Cs Cesium 132.91 | 56 Ba Barium 137.33 | 57-71 Lanthanides | 72 Hf Hafnium 178.49 | 73 Ta Tantalum 180.95 | 74 W Tungsten 183.85 | 75 Re Rhenium 186.21 | 76 Os Osmium 190.23 | 77 Ir Iridium 192.22 | 78 Pt Platinum 195.08 | 79 Au Gold 196.97 | 80 Hg Mercury 200.59 | 81 Tl Thallium 204.38 | 82 Pb Lead 207.20 | 83 Bi Bismuth 208.98 | 84 Po Polonium [208.98] | 85 At Astatine 209.98 | 86 Rn Radon 222.02 |
| 87 Fr Francium 223.02 | 88 Ra Radium 226.03 | 89-103 Actinides | 104 Rf Rutherfordium [261] | 105 Db Dubnium [262] | 106 Sg Seaborgium [266] | 107 Bh Bohrium [264] | 108 Hs Hassium [269] | 109 Mt Meitnerium [268] | 110 Ds Darmstadtium [269] | 111 Rg Roentgenium [272] | 112 Cn Copernicium [277] | 113 Uut Ununtrium unknown | 114 Fl Flerovium [289] | 115 Uup Ununpentium unknown | 116 Lv Livermorium [298] | 117 Uus Ununseptium unknown | 118 Uuo Ununoctium unknown |

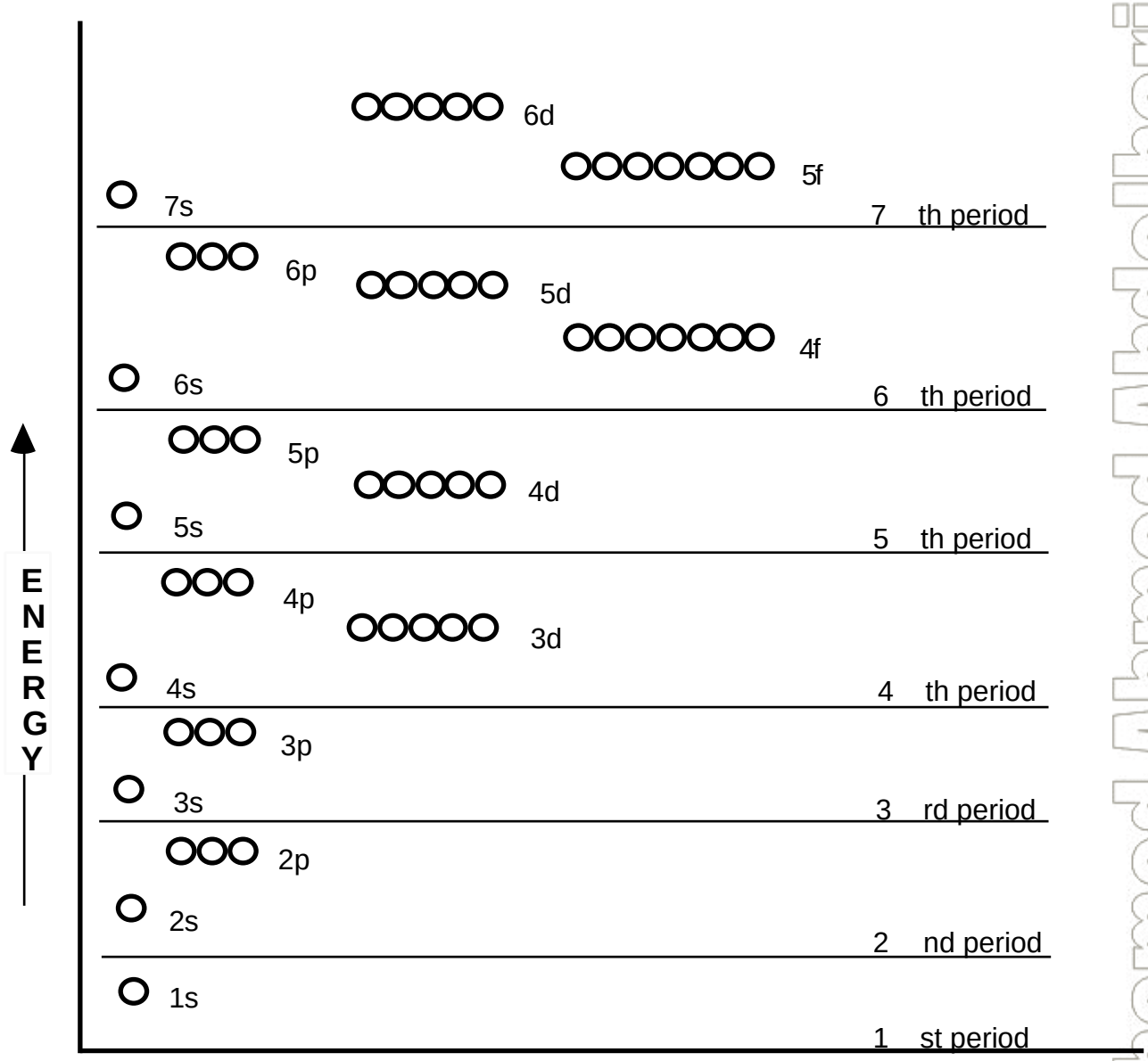
| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 57 La Lanthanum 138.91 | 58 Ce Cerium 140.12 | 59 Pr Praseodymium 140.91 | 60 Nd Neodymium 144.24 | 61 Pm Promethium 144.91 | 62 Sm Samarium 150.36 | 63 Eu Europium 151.97 | 64 Gd Gadolinium 157.25 | 65 Tb Terbium 158.93 | 66 Dy Dysprosium 162.50 | 67 Ho Holmium 164.93 | 68 Er Erbium 167.26 | 69 Tm Thulium 168.93 | 70 Yb Ytterbium 173.04 | 71 Lu Lutetium 174.97 |
| 89 Ac Actinium 227.03 | 90 Th Thorium 232.04 | 91 Pa Protactinium 231.04 | 92 U Uranium 238.03 | 93 Np Neptunium 237.05 | 94 Pu Plutonium 244.06 | 95 Am Americium 243.06 | 96 Cm Curium 247.07 | 97 Bk Berkelium 247.07 | 98 Cf Californium 251.08 | 99 Es Einsteinium [254] | 100 Fm Fermium 257.10 | 101 Md Mendelevium 258.10 | 102 No Nobelium 259.10 | 103 Lr Lawrencium [262] |

## Electron Configuration

**Brief Instructions**

- **An electron configuration** is a method of indicating the arrangement of electrons around a nucleus.
- A typical electron configuration consists of numbers, letters, and superscripts with the following format:

1. A number indicates the energy level.
2. A letter indicates the type of orbital; s, p, d, f.
3. A superscript indicates the number of electrons in the orbital.



## Configuration Writing Practice

***24) Write a ground state electron configuration for each neutral atom.***

| Na | Pb | Sr | U | N | Ag | Ti | Ce | Cl | Hg |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

***25) If each orbital can hold a maximum of two electrons, how many electrons can each of the following hold?***

| 2s | 5p | 4f | 3d | 4d |
|---|---|---|---|---|
| | | | | |

*1) How many s orbitals can there be in an energy level?*_____

*2) How many electrons can occupy an s orbital? ?*_____

*3) How many p orbitals can there be in an energy level? ?*_____

*4) Which is the lowest energy level that can have a s orbital? ?*_____

*5) Which is the lowest energy level that can have a p orbital? ?*_____

***6)** How many d orbitals can there be in an energy level? ?*_____

*7) How many d electrons can there be in an energy level? ?*_____

*8) Which is the lowest energy level having d orbitals? ?*_____

*9) How many f electrons can there be in an energy level? ?*_____

*10) Which is the lowest energy level having f orbitals? ?*_____

*11) How many f orbitals can there be in an energy level? ?*_____

*12) How many energy levels are partially or fully occupied in a neutral atom of calcium?*

_____

*13) Which sublevels of the 3rd energy level are filled (a) in the element argon (b) in the element krypton?* _____

*14) What is the maximum number of electrons that can be present in an atom having three principal energy levels ?*_____

*26) Complete the following chart:*

| Element | Atomic number | Number electrons in each E level | Electron Configuration |
|---|---|---|---|
| O | 8 | 2, 6 | $1s^2\ 2s^2 2p^4$ |
| Na | 11 | 2, 8, 1 | $1s^2\ 2s^2 2p^6\ 3s^1$ |
| S | | | |
| K | | | |
| Al | | | |
| Cl | | | |
| Xe | | | |
| Ca | | | |
| F | | | |
| Br | | | |
| N | | | |
| Ar | | | |
| I | | | |
| Sr | | | |
| Mg | | | |
| Sc | | | |
| As | | | |
| Br | | | |
| Li | | | |
| Hg | | | |
| Fe | | | |

*27) Determine what elements are denoted by the following electron configurations:*

a) $1s^2 2s^2 2p^6 3s^2 3p^4$ _____

b) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$ _____

c) [Kr] $5s^2 4d^{10} 5p^3$ _____

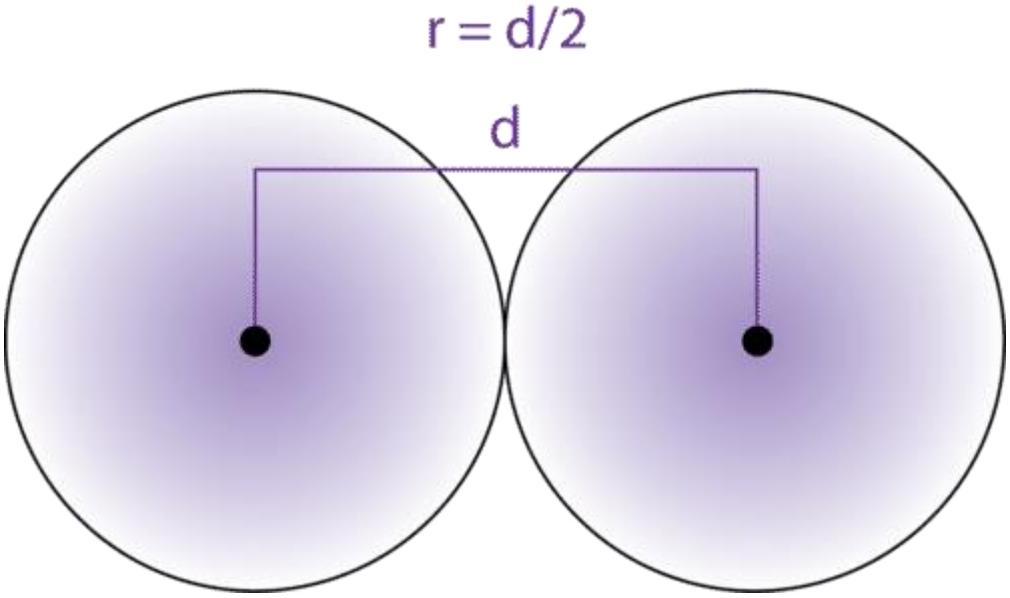
d) [Xe] $6s^2 4f^{14} 5d^6$ _____

e) [Rn] $7s^2 5f^{11}$ _____

# Atomic Radius

The size of an atom is defined by the edge of its orbital. However, orbital boundaries are fuzzy and in fact are variable under different conditions. In order to standardize the measurement of atomic radii, the distance between the nuclei of two identical atoms bonded together is measured.

**The atomic radius** is defined as one-half the distance between the nuclei of identical atoms that are bonded together.

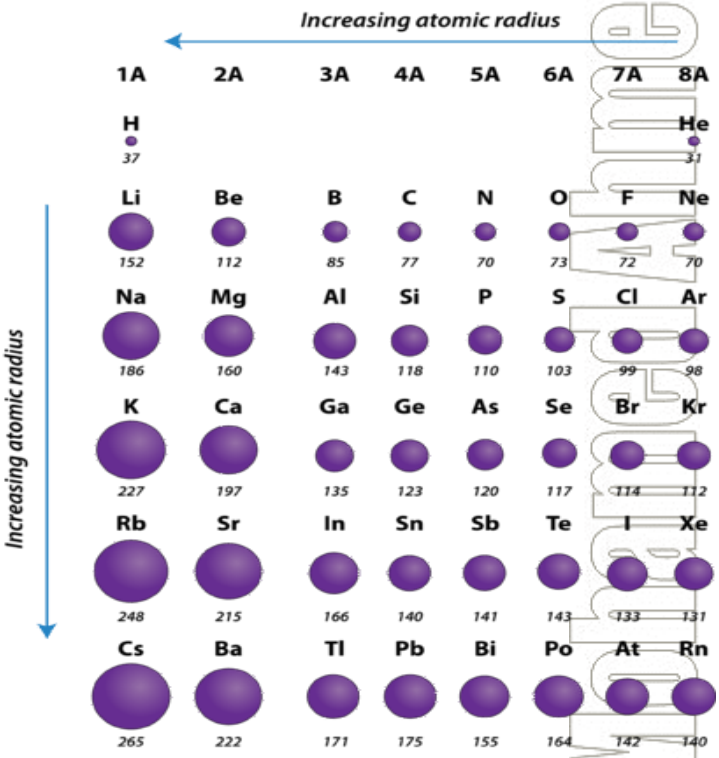



The units for atomic radii are picometers, equal to $10^{-12}$ meters.

As an example, the internuclear distance between the two hydrogen atoms in an1 $H_2$ molecule is measured to be 74 pm. Therefore, the atomic radius of a hydrogen atom is 742=37 pm.

## Trends within periods

The atomic radius of atoms generally decreases from left to right across a period. Within a period, protons are added to the nucleus as electrons are being added to the same principal energy level. These electrons are gradually pulled closer to the nucleus because of its increased positive charge. *Since the force of attraction between nuclei and electrons increases, the size of the atoms decreases.*



## Trends within groups

The atomic radius of atoms generally increases from top to bottom within a group. As the atomic number increases down a group, there is again an increase in the positive nuclear charge. However, there is also an *increase in the number of occupied principle energy levels*.

### Summary

- Atomic radius is determined as the distance between the nuclei of two identical atoms bonded together.
- The atomic radius of atoms generally decreases from left to right across a period.
- The atomic radius of atoms generally increases from top to bottom within a group.

### Review

***28) Define "atomic radius."***

***29) What are the units for measurement of atomic radius?***

***30) How does the atomic radius change across a period?***

***31) How does atomic radius change from top to bottom within a group?***

***32) Explain why the atomic radius of hydrogen is so much smaller that the atomic radius for potassium.***

***33) Rank the following elements by increasing atomic radius: carbon, aluminum, oxygen, potassium.***

# ions

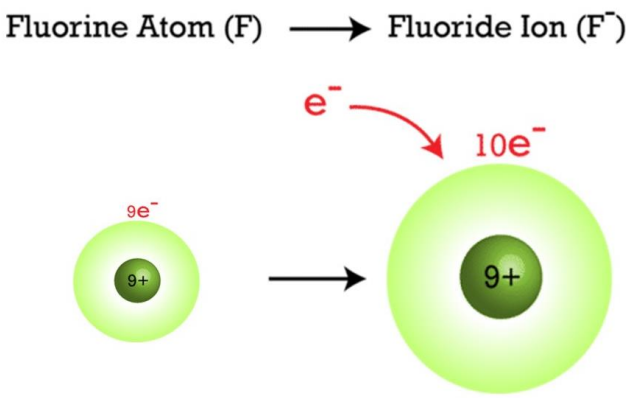
## Atoms Are Neutral

An atom always has the *same number of electrons as protons*. Electrons have an electric charge of -1 and protons have an electric charge of +1. Therefore, the charges of an atom's electrons and protons "cancel out." This explains why *atoms are neutral in electric charge.*

**Q:** What would happen to an atom's charge if it were to gain extra electrons?

**A:** If an atom were to gain extra electrons, it would have more electrons than protons. This would give it a negative charge, so it would no longer be neutral.

## Atoms to Ions




Atoms cannot only gain extra electrons. They can also lose electrons. In either case, they become **ions**. *Ions are atoms that have a positive or negative charge because they have unequal numbers of protons and electrons*. If atoms lose electrons, they become **positive ions**, or cations. If atoms gain electrons, they become **negative ions**, or anions. Consider the example of fluorine. A fluorine atom has nine protons and nine electrons, so it is electrically neutral. If a fluorine atom gains an electron, it becomes a fluoride **ion** with an electric charge of -1.

## Removing more than one electron

**Successive Ionization Energies for the Period 2 Elements**

| Element | Valence Electrons | Ionization Energy (kJ/mol)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th |
| Li | 1 | 520 | 7300 | | | | | | | |
| Be | 2 | 900 | 1760 | 14,850 | | | | | | |
| B | 3 | 800 | 2430 | 3660 | 25,020 | | | | | |
| C | 4 | 1090 | 2350 | 4620 | 6220 | 37,830 | | | | |
| N | 5 | 1400 | 2860 | 4580 | 7480 | 9440 | 53,270 | | | |
| O | 6 | 1310 | 3390 | 5300 | 7470 | 10,980 | 13,330 | 71,330 | | |
| F | 7 | 1680 | 3370 | 6050 | 8410 | 11,020 | 15,160 | 17,870 | 92,040 | |
| Ne | 8 | 2080 | 3950 | 6120 | 9370 | 12,180 | 15,240 | 20,000 | 23,070 | 115,380 |

* mol is an abbreviation for mole, a quantity of matter.

After removing the first electron from an atom, it is possible to remove additional electrons. The amount of energy required to remove a second electron from a 1+ ion is called the **second ionization energy**, the amount of energy required to remove a third electron from a 2+ ion is called the **third ionization energy**, and so on.

Reading across **Table** from left to right, you will see that the energy required for each successive ionization always increases. However, the increase in energy does not occur smoothly. Note that for each element there is an ionization for which the required energy increases dramatically.

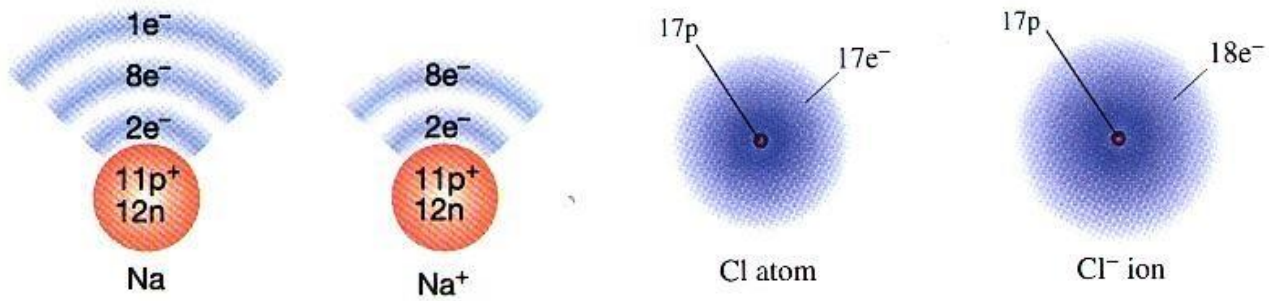
## OCTET RULE

Most elements, except noble gases, combine to form compounds. Compounds are the result of the formation of chemical bonds between two or more different elements.

- In the formation of a chemical bond, atoms lose, gain or share valence electrons to complete their outer shell and attain a noble gas configuration.
- This tendency of atoms to have eight electrons in their outer shell is known as the ***octet rule***.

### Formation of Ions:

- An ***ion*** (charged particle) can be produced when an ***atom gains*** or ***loses*** one or more ***electrons***.




## IONIC CHARGES

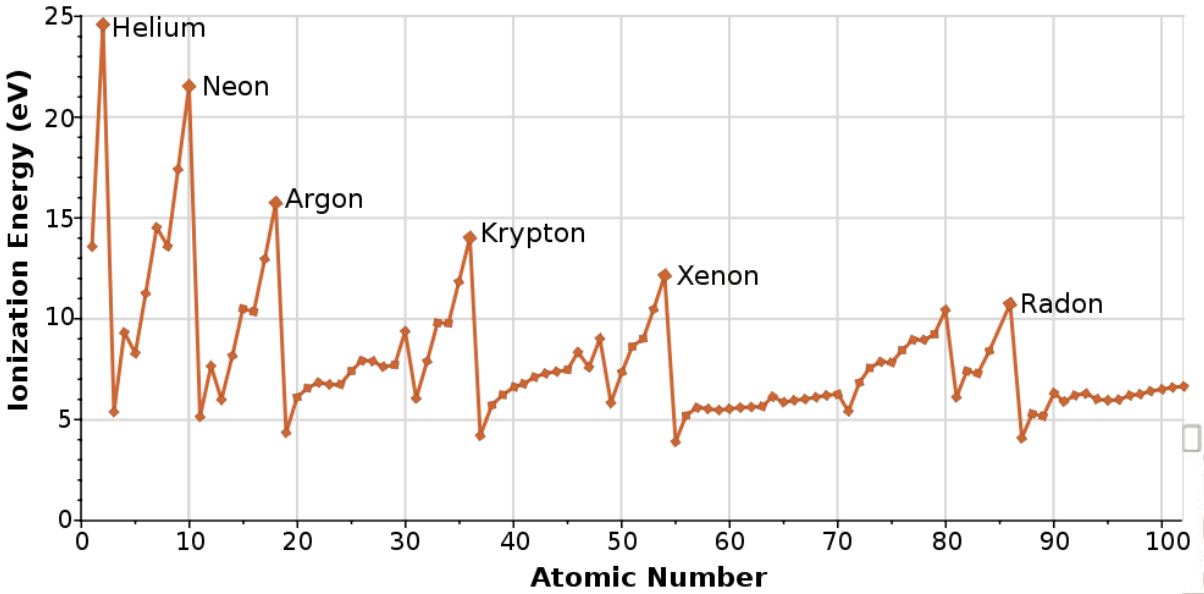
The ionic charge of an ion is dependent on the number of electrons lost or gained to attain a noble gas configuration.

For most main group elements, the ionic charges can be determined from their group number,

| | | Metals Lose Valence Electrons | | | Nonmetals Gain Valence Electrons | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Noble Gases | | 1A (1) | 2A (2) | 3A (13) | 5A (15) | 6A (16) | 7A (17) | | Noble Gases |
| He | ⇦ | $Li^+$ | | | | | | | |
| Ne | ⇦ | $Na^+$ | $Mg^{2+}$ | $Al^{3+}$ | $N^{3-}$ | $O^{2-}$ | $F^-$ | ⇨ | Ne |
| Ar | ⇦ | $K^+$ | $Ca^{2+}$ | | $P^{3-}$ | $S^{2-}$ | $Cl^-$ | ⇨ | Ar |
| Kr | ⇦ | $Rb^+$ | $Sr^{2+}$ | | | | $Br^-$ | ⇨ | Kr |
| Xe | ⇦ | $Cs^+$ | $Ba^{2+}$ | | | | $I^-$ | ⇨ | Xe |

# Ionization Energy

**Ionization energy** is the energy required to remove an electron from a specific atom. It is measured in kJ/mol, which is an energy unit, much like calories.




## Trends within periods

Moving from left to right across the periodic table, the ionization energy for an atom increases. We can explain this by considering the nuclear charge of the atom. The more protons in the nucleus, the stronger the attraction of the nucleus to electrons. This stronger attraction makes it more difficult to remove electrons.

## Trends within groups

Within a group, the ionization energy decreases as the size of the atom gets larger. On the graph, we see that the ionization energy increases as we go up the group to smaller atoms. In this situation, the first electron removed is farther from the nucleus as the atomic number (number of protons) increases. Being farther away from the positive attraction makes it easier for that electron to be pulled off.

## Summary

- Ionization energy refers to the amount of energy needed to remove an electron from an atom.
- Ionization energy decreases as we go down a group.
- Ionization energy increases from left to right across the periodic table.

## Review

34) *Define "ionization energy."*

35) *Do valence electrons have larger or smaller ionization energies that the inner-*shell *electrons*?

36) *Describe the trends in ionization energy from left to right across the periodic table.*

37) *Describe the trends in ionization energy from top to bottom of a group in the periodic table.*

38) *Circle the atom in each pair that has the greater ionization energy.*

| | | |
|---|---|---|
| a. Li or Be | b. Ca or Ba | c. Na or K |
| d. P or Ar | e. Cl or Si | f. Li or K |

39) *Explain the relationship between the relative size of an ion to its neutral atom* and *the charge on the ions.*

40) *Rank each of the following in order of INCREASING ionization energy*

a. O, S, Ge _____

b. Be, Ba, B _____

41) *Rank each of the following in order of DECREASING ionization energy*

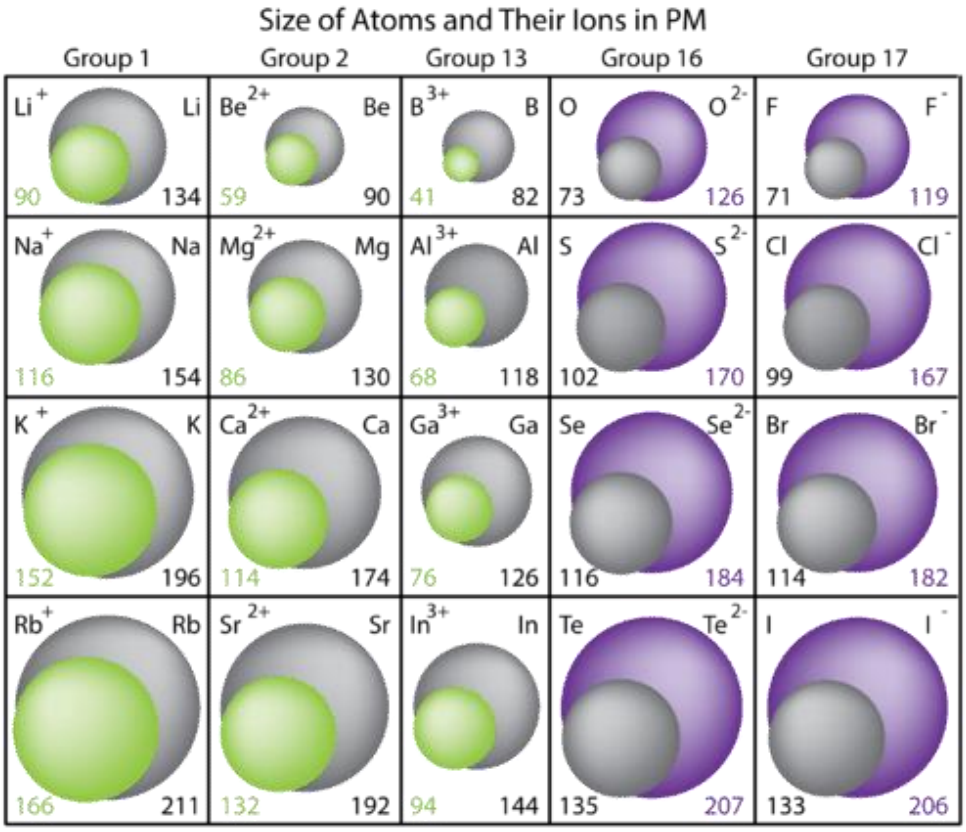
a. Cl, Cu, Au _____

b. Te, Sb, Xe _____

c.

# ionic Radius

The **ionic radius** for an atom is measured in a **crystal lattice**, requiring a solid form for the compound.




The removal of electrons always results in a cation that is considerably smaller than the parent atom.

***Why?***

1) When the valence electron(s) are removed, the resulting ion has one fewer occupied principal energy level, so the electron cloud that remains is smaller
2) Another reason is that the remaining electrons are drawn closer to the nucleus because the protons now outnumber the electrons.

One other factor is the number of electrons removed. The potassium atom has one electron removed to for the corresponding ion, while calcium loses two electrons.

The addition of electrons always results in an anion that is larger than the parent atom.

***Why?***

1) When the electrons outnumber the protons, the overall attractive force that the protons have for the electrons is decreased.
2) The electron cloud also spreads out because more electrons results in greater electron-electron repulsions

## Trends within periods

As you move across the table from left to right the size of positive ion decrease gradually. Then, beginning in group 15 or 16 the size of the much larger negative ions also decreases.

## Trends within groups

As you move down a group, the size of positive and negative ions increase because of adding more and more energy levels.

## Summary

- Ionic radius is determined by measuring the atom in a crystal lattice.
- Removal of electrons results in an ion that is smaller than the parent element.
- Addition of electrons results in an ion that is larger than the parent atom.

## Review

***42) Explain why the radius of the rubidium ion is smaller than the radius of the rubidium atom.***

***43) Explain why the radius of the tellurium ion is larger than the radius of the tellurium atom.***

***44) Why is the oxygen anion larger than the fluoride anion?***

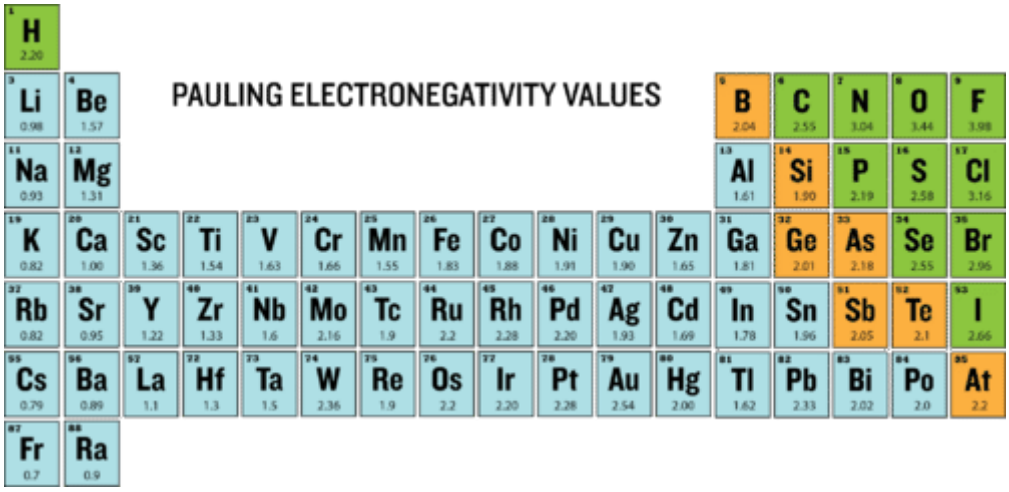
***45) Why is the sodium cation larger than the magnesium cation?***

## Electronegativity

Valence electrons of both atoms are always involved when those two atoms come together to form a chemical bond. Chemical bonds are the basis for how elements combine with one another to form compounds. When these chemical bonds form, **atoms of some elements have a greater ability to attract the valence electrons involved in the bond than other elements**.

**Electronegativity** is a measure of the ability of an atom to attract the electrons when the atom is part of a compound.

Electronegativity is not measured in energy units, but is rather a relative scale. All elements are compared to one another, with the most electronegative element, **fluorine, being assigned an electronegativity value of 3.98**. Fluorine attracts electrons better than any other element. The table below shows the electronegativity values for the elements.




The electronegativity scale was developed by Nobel Prize winning American chemist Linus Pauling. The largest electronegativity (3.98) is assigned to fluorine and all other electronegativities measurements are on a relative scale.

Because most noble gases do not form compounds, they do not have electronegativities.

### Summary

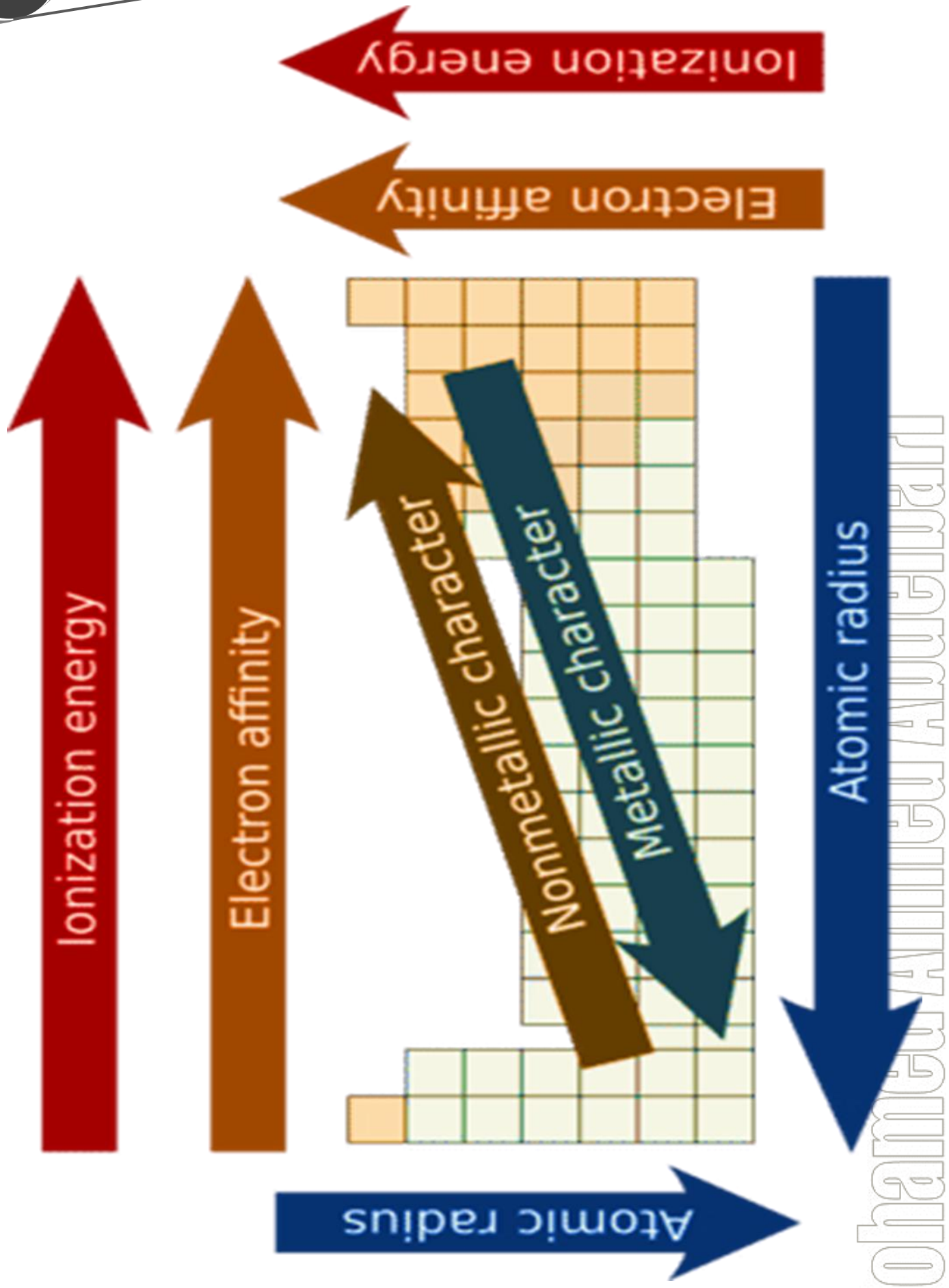
- Electronegativity is a measure of the ability of an atom to attract the electrons when the atom is part of a compound.
- The highest electronegativity value is for fluorine.

### Review

*46) Define "electronegativity."*

_____

_____


Ionization energy
Electron affinity
Nonmetallic character
Metallic character
Atomic radius
Atomic radius
Ionization energy
Electron affinity