Chapter 3

PERIODIC TABLE AND PERIODICITY OF PROPERTIES

Time Allocation

Teaching periods	= 08
Assessment period	= 02
Weightage	= 08

Major concepts

3.1 Periodic Table.

3.2 Periodicity of properties.

STUDENTS LEARNING OUT COMES (SLO'S)

Student will be able to:

- State the periodic law.
- Distinguish between a period and a group in the periodic table.
- Classify the elements (into two categories: groups and periods) according to the configuration of their outer most electrons.
- Determine the demarcation of the periodic table into an s-block, p-block, d-block and f-block
- Construct the shape of the periodic table.
- Determine the location of families on the Periodic Table.
- Recognize the similarity in the chemical and physical properties of elements in the same family of elements.
- Identify the relationship between electron configuration and the position of an element on the periodic table.
- Explain how shielding effect influences periodic trends.
- Describe how electro negativitiy, electron affinity, atomic radii and ionization energy change within a group and within a period in the periodic table.

Introduction:

The periodic table of Elements which you see in front of any classroom or chemistry laboratory. You take it for granted but this is the product of hundreds years struggle of scientists to understand the complexity of this world as Elements . When a large number of elements discovered, scientists decided to arrange the elements in certain order.

First of all German chemist Dobereiner proposed classification of Triads in which several groups of three elements classified on the basis of atomic masses. In this Triad central element had atomic mass approximately equal to average of mass of the other two elements. For example, Calcium (40), Strontium (87.6) and barium (137). In which mass of strontium is average of atomic masses of calcium and barium.

Table 3.1 Dobereiner classification of traids

ELEMENTS		ATOMIC MASS	ARITHMATIC MEAN
Traids	Lithium Sodium Potassium	7 23 39	$\frac{7 + 39}{2} = 23$
Triads	Chlorine bromine Iodine	35.5 80 126.5	$\frac{35.5 + 126.5}{2} = 81$
Triads	Calcium Strontium Barium	40 87.6 137	$\frac{137 + 40}{2} = 88.5$

In 1864 British chemist Newland put forwarded Law of Octaves and arranged the elements in order of increasing atomic masses. According to him if elements are arranged in increasing order of their masses then eighth element has similar properties as of first element in a group. For example:

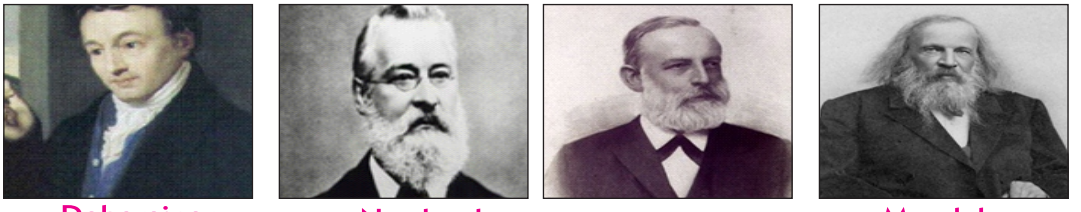
Table 3.2 Newlands Classification octaves

Li=7 Be=9 B=11 C=12 N=14 O=16 F=19

Na=23 Mg=24 Al=27.3 Si=28 P=30 S=32 Cl=35.5

In the above arragement Li and Na, Be and Mg, B and Al, C and Si, N and P, O and S, F and Cl shows same chemical properties.

In 1869 Mendeleev published a periodic table containing eight vertical columns (groups) and horizontal rows(periods)on the basis of physical and chemical properties of elements. In 1869 German scientist Lother Meyer published a periodic table in which 56 elements were arranged in 9 vertical columns or groups on the basis of atomic masses



Dobereiner Newland Lother Meyer Mendeleev

Fig 3.1 Scientists participated in classification of Periodic table

3.1 PERIODIC TABLE

Mendeleev's periodic table was the first attempt to arrange the elements although this periodic table was failed due to many demerits but provided the base for discovery of Periodic Law. On the basis of periodic Law a periodic table developed in which vertical columns are called groups and horizontal rows are called periods. This periodic table predict the properties of elements.

3.1.1 Periodic Law:

In 1869 Mendeleev Proposed a periodic law on the basis of physical and chemical properties empirically. Periodic law states that " The Properties of the elements are a periodic Function of their atomic weight". In certain cases Mendeleev left gaps, which were modified by Moseley.

3.1.2 Modern Periodic Table

Atomic number is fundamental property because it increases regularly element to element and is fixed for every element. It was noticed in arrangement of elements that atomic number increasing from left to right in a horizontal row and properties of elements were found repeating after regular intervals. Due to this reason elements of same properties and same electronic configuration are placed in the same group.

In 1913 Moseley discovered that Atomic number is the basic property of an atom. He proposed a modern periodic law. The Moseley states that " The Physical and chemical Properties of elements are the periodic function of their atomic numbers" Atomic number of an element is equal to the number of electrons in a neutral atom so atomic number also provides the electronic configuration of elements of periodic table. So on the basis of Electronic configuration elements are arranged in long form of periodic table and Periodic table is composed with 7 rows and 18 columns.

Periods in Periodic Table:

There are seven horizontal rows in periodic table known as periods. In periods physical and chemical properties changes from left to right. Elements of a period shows different properties because The electronic configuration continuously changing within a period and number of valence electrons decide the position of element in a period. These periods are categorized as short periods and long periods. Which are as follows.

First Period(shortest period)

- This period contains only two elements Hydrogen (H) and Helium (He).
- K-shell is filled in this period.

Second and Third Period(Short Period)

- Each period contain eight elements.
- In these Periods L and M shells are being filled by electrons.
- Second period contains Li, Be, B, C, N, O,F and Ne.
- Third period contains Na, Mg, Al, Si, P,S, Cl, and Ar.

Fourth and Fifth Period(Long Period)

- Each period contain 18 elements.
- In these periods M and N shells are being filled by electrons.
- Fourth period starts from Potassium (K) and ends on Krypton (Kr).
- Fifth period starts from Rubidium (Rb) and ends on Xenon (Xe).

Sixth Period(Longest Period)

- This period contains 32 elements.
- The 14 elements in the bottom are named as Lanthanides.
- Sixth periods starts from Caesium (Cs) and ends with Radon (Rn).

Seventh Period (Incomplete Period)

- This period starts from Francium (Fr)
- This period is consider as incomplete.
- This period contains a group of 14 elements known as Actinides.

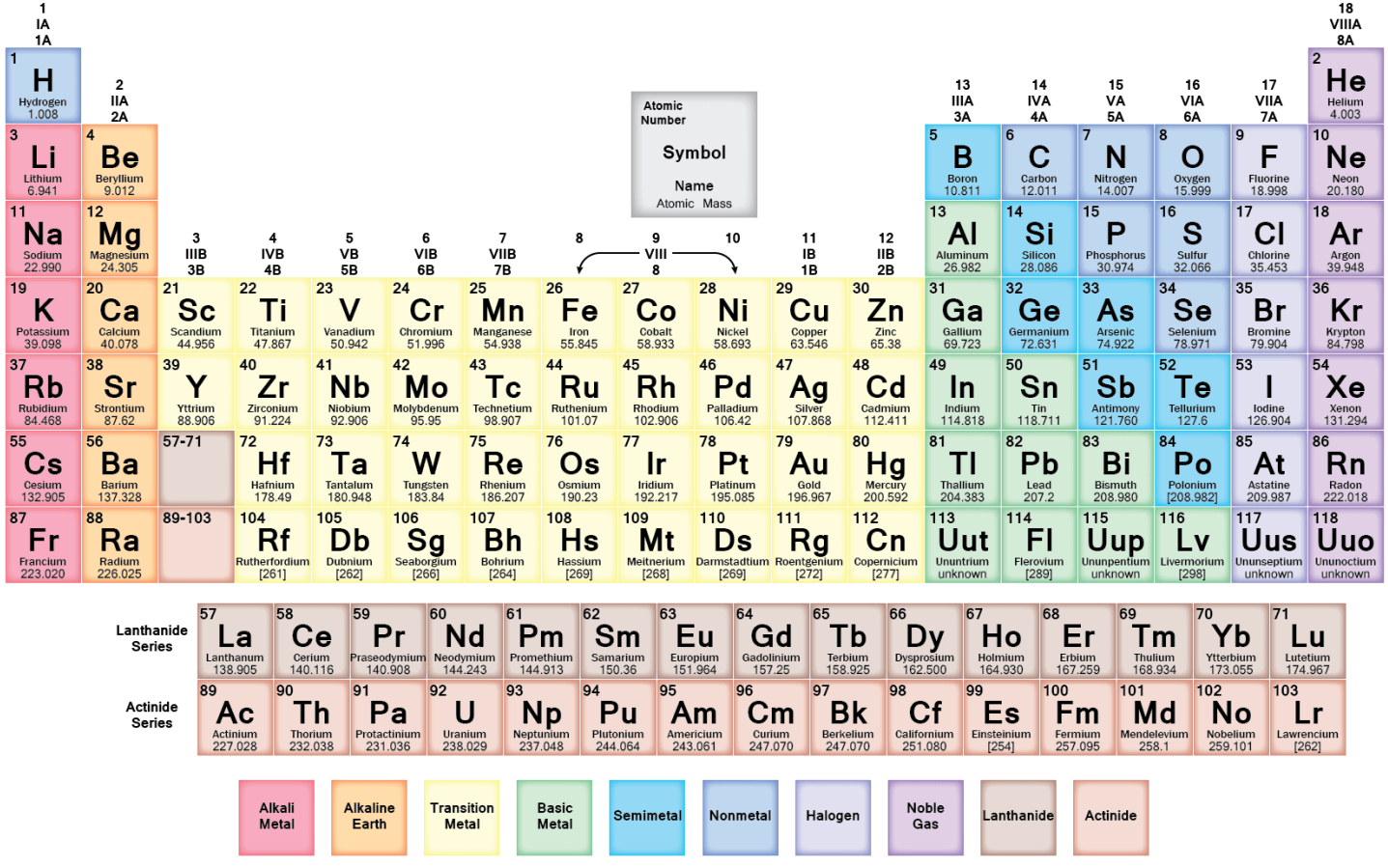
All the periods except the first period start with an alkali metal and end at a Nobel gas. It is observed that number of elements are fixed in each period because of maximum number of electrons accommodation in the particular valence shell of elements. Which is shown in the following table 3.2.

Table 3.2 Period wise Atomic Number of Elements in Periodic Table

Period Number	Number of Elements	Range of Atomic Number
First	2	1 to 2
Second	8	3 to 10
Third	8	11 to 18
Fourth	18	19 to 36
Fifth	18	37 to 54
Sixth	32	55 to 86
Seventh	[32]*	87 to 118*

(Where * Shows incomplete period)

Periodic Table of elements



Groups in Periodic Table:

There are Eighteen vertical columns in periodic table known as groups. The sub groups are divided on the basis of their similar properties as A and B and placed together in periodic table.

The elements of sub group A are called Main or Representative Elements.

The elements of sub group B are called Transition Elements. The group number indicate total number of electrons in valence shell of the element.

Group I A (Alkali Metal) or Lithium Family:

- This Group include Lithium (Li), Sodium (Na), Potassium (K), Rubidium (Rb), Cesium (Cs) and Francium (Fr).
- Their Valence shell contain one electron.
- On reaction they lose one electron and form univalent positive ion (cation).
- They are highly reactive metals.
- They have low melting point.

Do you know?

Francium(Fr) is radioactive element of IA group.

Group II A(Alkaline Earth Metals) or Beryllium Family:

- This Group include Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium (Ra).
- Their Valence shell contain two electrons.
- On reaction they lose two electrons and form divalent positive ion.
- They show irregular Densities, Melting and Boiling point.

Do you know?

Radium (Ra) is radioactive element of IIA group.

Group III A(Boron Family) :

- This Group include Boron (B), Aluminum (Al), Gallium (Ga), Indium (In) And Thallium (Tl).
- Their valence shell contain three electrons.
- On reaction they lose three electrons and form trivalent positive ion except Boron.

Do you know?

Boron (B) is metalloid in III A group due to increase in atomic volume boron shows some properties of metals and some properties of non-metals.

Group IV A(Carbon Family) :

- This Group include carbon (C),silicon (Si), Germanium (Ge), Tin (Sn) and Lead (Pb).
- Their valence shell contain four electrons.

- C,Si and Ge form covalent bond, whereas Sn and Pb exhibit variable Valencies 2 and 4.
- Carbon is nonmetal, Silicon , Germanium are metalloids and Tin and Lead are metals.

Group V A(Nitrogen Family) :

- This Group include Nitrogen (N), Phosphorus (P), Arsenic (As), Antimony (Sb) and Bismuth (Bi).
- Their valence shell contains five electrons.
- They show large variations in their properties as we go down the group.
- Except Nitrogen all exist in allotropic form.

Do you know?

Carbon and Tin exist in allotropic form in IVA group, due to increase in atomic radii and volume, addition of new shell takes place.

Group VI A(Oxygen Family) :

- This Group include Oxygen(O) ,Sulphur (S),Selenium (Se), Tellurium (Te) and Polonium (Po).
- Their valance shell contain six elements.
- All of these elements exist in allotropic forms.
- Oxygen and sulphur are nonmetals, polonium is metal and all other are metalloids.

Group VII A(Halogen Family) :

- This Group include Fluorine (F),Chlorine(Cl),Bromine(Br),Iodine(I) and Astatine(At).
- Their valence shell contain seven electrons.
- Except Astatine (metal) all are nonmetals.
- Fluorine and chlorine are gases, bromine is liquid and iodine is solid at room temperature.

Group VIII A(Inert or Nobel gases):

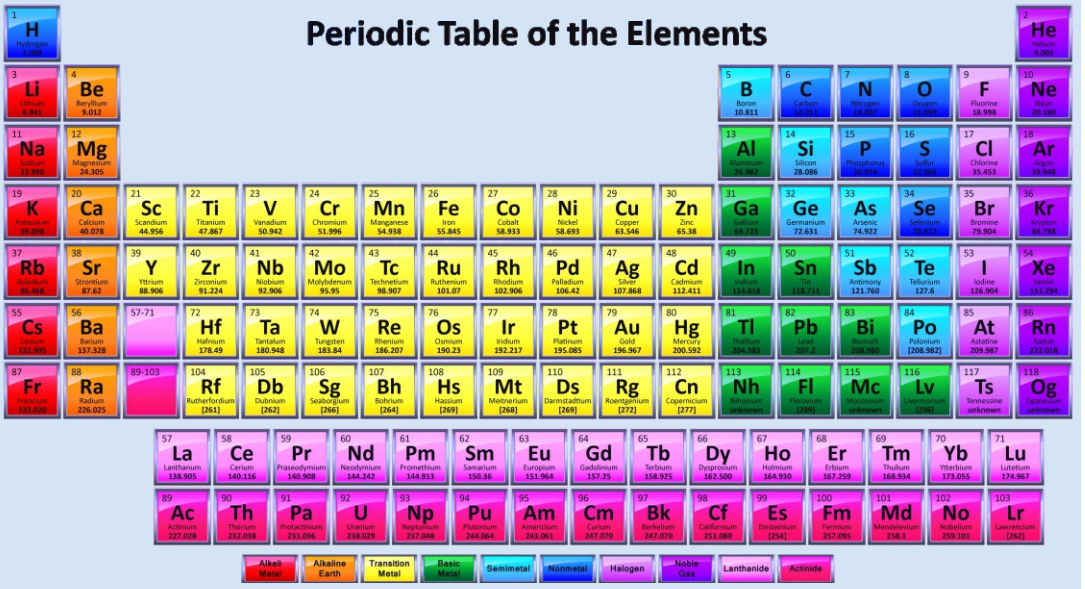
- This Group include Helium(He), Neon(Ne), Argon(Ar), Krypton (Kr) Xenon(Xe) and Radon(Rn).
- Their valence shell contain eight electrons except Helium which contain two electrons.

Group IB to VIII B(Transition Elements):

- These Groups are metals.
- In chemical reactions they shows Variable valencies.
- Their valence shells are incomplete.

Test Yourself

(1) look at the given periodic table carefully and answer the following questions



- Identify and list down the solid, liquid and gases at room temperature from the given periodic table.
- Identify and name the artificial elements from the periodic table gives above.
- Identify and list down the radioactive elements.
- Identify alkali , alkaline , transition metals.
- Identify and list down metalloids , lanthanide and actinide.

3.1.3 Demarcation of periodic table in s, p, d and f blocks:

The periodic table has been divided into four blocks, s , p , d , and f based on electronic confiauration.

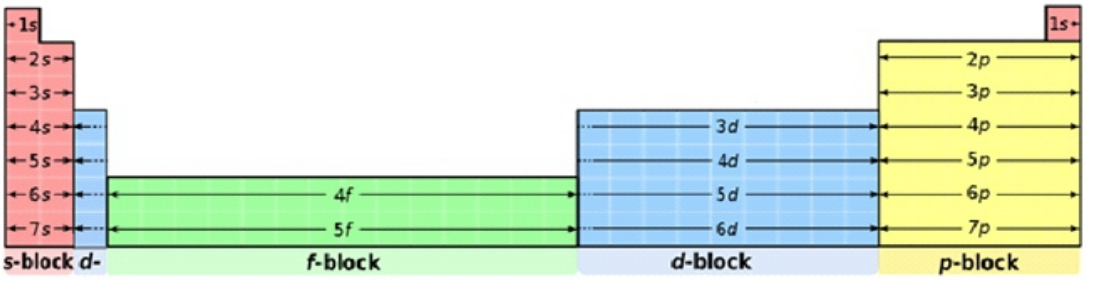


Fig 3.2

Nobel Gases: They are colorless, unreactive and diamagnetic, They are placed in zero group. Their electronic configuration is ns^2 ,np^6 and are exceptionally stable.

Representative Elements It includes metals and nonmetals. Some are diamagnetic and some are paramagnetic and marked as S block and P block elements.

(I) s-Block Elements: In **s** block elements electrons occupy in ns orbital. The elements of group IA and IIA are s block elements. Their electronic configuration varies ns^1 to ns^2.

(II) p-Block Elements: In **p** block elements electrons begin to fill np^1 to np^6. Elements of group IIIA to VIIA and zero group except He are also p block elements.

d-block Elements (Outer Transition Elements): These elements are metals but their properties are different from metals of representative elements i.e. Melting point, Boiling Point, variable oxidation state color compounds etc. In these elements electron fills in ns^2 $(n-1)$ d^{1-10} orbital. d-block elements consist of three series.

f-Block Elements (Inner Transition Elements): The elements in which inner f-orbital is filled, are called f block elements. They exhibit electronic configuration $ns^2(n-1)d^1(n-2)f^{1-14}$ There are two series called Lanthanides and Actinides.

3.2 PERIODICITY OF PROPERTIES:

The Periodicity means" Repeatation of some thing after some interval". The Periodicity of properties means that elements are arranged in an Order where properties of elements repeat after some period.

3.2.1 Atomic Size and Atomic Radius:

Atoms are so small that it is impossible to see atoms even with a powerful optical microscope. The size of a single atom therefore cannot be directly measured. however, techniques have been developed which can measure the distance between the centres of two bonded atoms of any elements. Half of this distance is considered to be the radius of the atom. It is measured in Angstrom unit (A) 1A = 1 0^{-8} cm

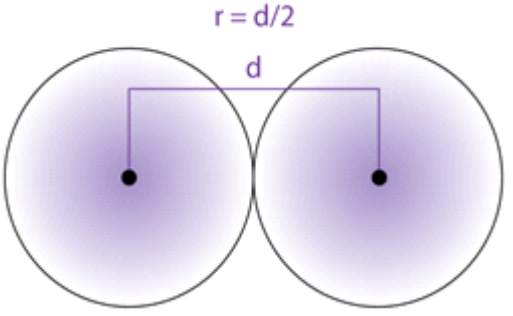


Fig 3.3 Atomic radius

In the periodic table, that atomic radius increases from top to bottom within a group due to increase in number of shells. However, as the atomic number increases from left to right, the atomic radius decrease. This gradual decrease in the radius is due to increase in the positive charge on the nucleus. As the positive nuclear charge increases, the negatively charged electrons in the shells are pulled closer to the nucleus. Thus, the size of the outermost shell becomes gradually smaller. This effect is quite remarkable in the elements of longer periods in which " d " and " f " sub shells are involved. For example, the gradual decrease in the size of Lanthanides is significant and called Lanthanide Contraction.

Table 3.4 Atomic radii decreases in period

2nd Periods elements	^{3}Li	^{4}Be	^{5}B	^{6}C	^{7}N	^{8}O	^{9}F	^{10}Ne
Atomic radii (pm)	152	113	88	77	75	73	71	69

Table 3.5 Atomic radii increases in group

1st group elements	Atomic radii (pm)
^{3}Li	152
^{11}Na	186
^{19}K	227
^{37}Rb	248
^{55}Cs	265

Note:
1A° = 100pm

3.2.2 Ionization Energy:

The ionization energy is minimum amount of energy required to remove an electron from a gaseous state and measured in joule/mole. The ionization energy depends upon atomic size and nuclear charge. The higher ionization energy means removal of electron is more difficult for example the ionization energy of hydrogen is 1312KJ/mole.

$$H(g) + \text{Energy} \longrightarrow H^{+}_{(g)} + e^{-} \quad (I.E = +1312 KJ/mol)$$

If we move from left to right in periods the value of ionization energy increases. Its because of size of atoms reduces and electrons are held strongly by the attractive force of nucleus. Due to this elements on the left side have less ionization energy. Which is shown in table 3.6.

Table 3.6 Ionization energy increases in period

Increase in ionization Energy of Elements in Periods of Periodic Table →

Elements of Second periods	^{3}Li	^{4}Be	^{5}B	^{6}C	^{7}N	^{8}O	^{9}F	^{10}Ne
Ionization Energy(kJ/mol	520	899	801	1086	1402	1314	1681	2081

As we move down the group ionization energy decreases from top to bottom due to additions of shells. Decrease in ionization energy is shown in table 3.7.

Increase in number of shells reduce the electrostatic force between electrons of valence shell and nucleus.

Table 3.7 Ionization Energy Decreases in group

↓

Elements of first group	Ionization energy (KJ/mol)
^{3}Li	520
^{11}Na	496
^{19}K	419
^{37}Rb	403
^{55}Cs	377

3.2.3 Electron Affinity

The electron affinity is amount of energy released when an electron is added in the outermost shell of a gaseous atom. It is also calculated in K J/mol. Affinity means attraction, therefore electron affinity means tendency to accept electron to form anion For example electron affinity of fluorine is -328 KJ/mol.

$$F_{(g)} + e^{-} \longrightarrow F^{-}_{(g)} \quad \Delta H = -328 \text{ KJ/mol}$$

In a period electron affinity increases from left to right due to decrease of atomic size because when size of atom decreases the attraction between nucleus and incoming electron increases and more energy is released.

Table 3.8 Electron affinity increases in period

Elements of Second periods	^{3}Li	^{4}Be	^{5}B	^{6}C	^{7}N	^{8}O	^{9}F	^{10}Ne
Electron Affinity (kJ/mol	-60	-48	-29	-122	-6.8	-141	-328	0

Electron Affinity decreases in group

In a group electron affinity values decrease from Top to bottom, because the size of atom increases.

Table 3.9 Electron Affinity decreases in Groups

Elements of 17th group	Electron Affinity (KJ/mol)
^{9}F	-328
^{17}Cl	-349
^{35}Br	-325
^{53}I	-295

Down the group attraction of incoming electron and Nucleus decreases and less energy released.

As the size of iodine is bigger than bromine its electron affinity is less than bromine.

The decrease of electron affinity is shown in table 3.9

3.2.4 Shielding Effect:

The shielding effect is defined as reduction in the effect of nuclear charge on the valence electron cloud, due to presence of inner shell electrons in an atom.

The electrons present between the nucleus and valence shell of atom reduce the nuclear charge effect on electrons present in outermost shell. As a result valence electron experience less nuclear charge than the actual charge. Therefore

"Electrons present in the inner shells Shield the force of attraction of nucleus felt by the valence shell electrons is called Shielding effect."

The Shielding effect increases down the group in periodic table and remain same in period from left to right. For example shielding effect in potassium atom is more than sodium atom.

Fig 3.4 Shielding effect in Potassium atom is more then Sodium atom

3.2.5 Electronegativity:

The ability of an atom to attract the shared pair of electrons towards itself in a molecule is called electronegativity. The trend of electronegativity is same as ionization energy and electron affinity. It increases from left to right in period due to increase in nuclear charge which decrease the distance from nucleus to shared electron pair (table 3.10). It increases the power to attract the shared pair of electrons.

Table 3.10 Electronegavity Increases in periods

Elements of Second periods	^{3}Li	^{4}Be	^{5}B	^{6}C	^{7}N	^{8}O	^{9}F
Electronegativity	1.0	1.6	2.0	2.6	3.0	3.4	4.0

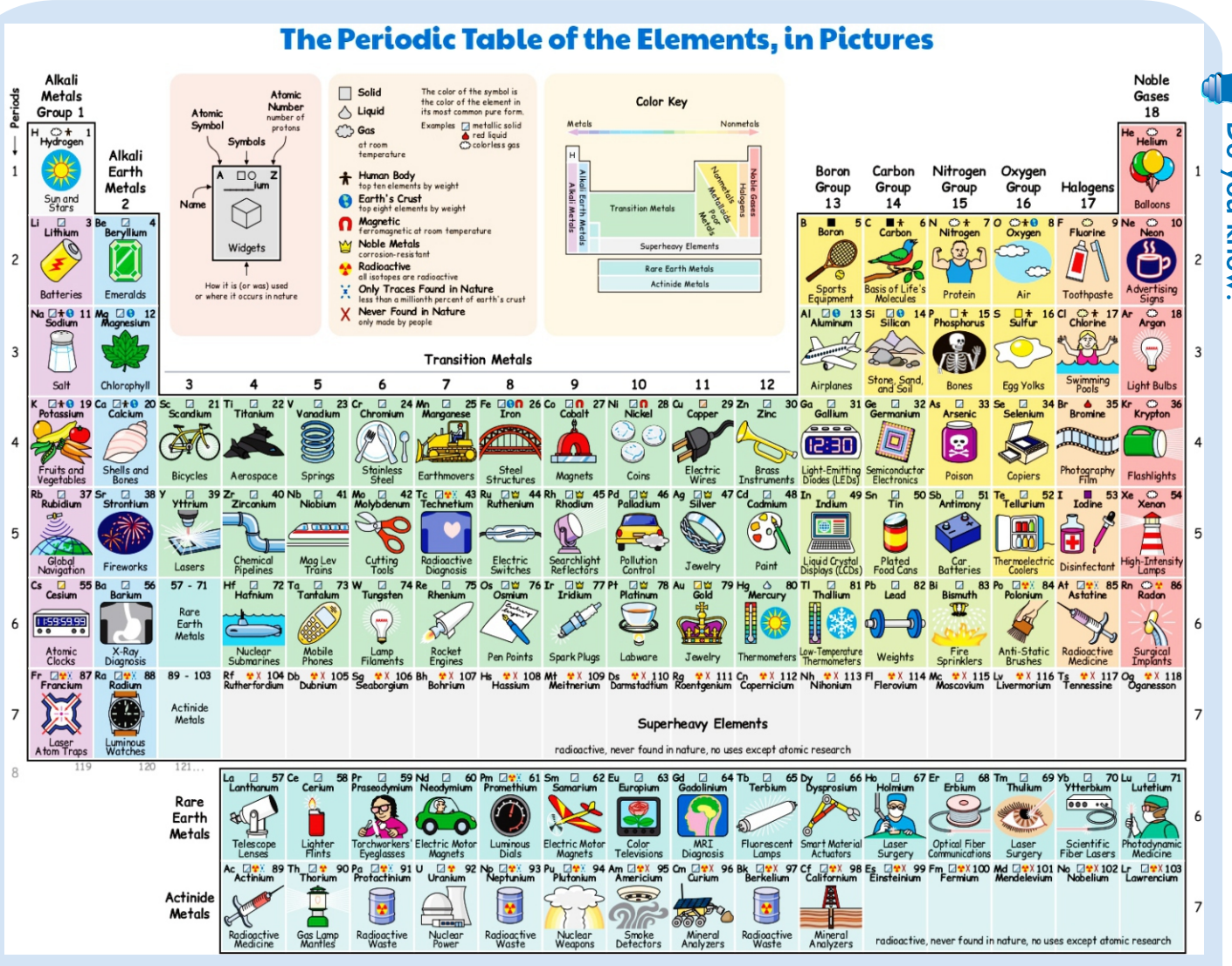
In group electronegativity decreases because size of Atom increases and attraction for shared electron pair decreases: for example in table 3.11 Electronegativity of halogens are given.

Table3.11 Electronegativity decreases in group

Elements of 17th group	Electronegativity
^{9}F	4.0
^{17}Cl	3.2
^{35}Br	3.0
^{53}I	2.7

Test Yourself

- What is trend of atomic radius in group?
- Why do bigger size atoms have more shielding effects?
- Which element have highest ionization energy and why?


The Periodic Table of the Elements, in Pictures
Periods
Alkali Metals Group 1
Alkali Earth Metals 2
Transition Metals
Boron Group 13
Carbon Group 14
Nitrogen Group 15
Oxygen Group 16
Halogens 17
Noble Gases 18
Atomic Symbol
Atomic Number
number of protons
Symbols
Name
How it is (or was) used or where it occurs in nature
Solid
Liquid
Gas
at room temperature
The color of the symbol is the color of the element in its most common pure form.
Examples metallic solid
red liquid
colorless gas
Human Body
top ten elements by weight
Earth's Crust
top eight elements by weight
Magnetic
ferromagnetic at room temperature
Noble Metals
corrosion-resistant
Radioactive
all isotopes are radioactive
Only Traces Found in Nature
less than a millionth percent of earth's crust
Never Found in Nature
only made by people
Color Key
Metals
Nonmetals
Alkali Metals
Alkali Earth Metals
Transition Metals
Nonmetals
Metalloids
Poor Metals
Halogens
Noble Gases
Superheavy Elements
Rare Earth Metals
Actinide Metals
Rare Earth Metals
Actinide Metals
Superheavy Elements
radioactive, never found in nature, no uses except atomic research

Summary

- 19th century is considered as milestone in Systematic arrangment of elements in Periodic Table.
- Dobereiner arranged elements in Triads.
- Newland put forward Law of Octaves.
- Mendeleev Published Preiodic law with groups and Rows.
- Moseley stated his law as "The physical and chemical properties of elements are the periodic function of their atomic numbers"
- There are total eighteen groups and seven periods in modern periodic table.
- Physical and Chemical properties change from left to right in a period. Elements of a period show different properties because the electronic configuration continuously changes within a period.
- The sub groups are divided on the basis of their similar properties as A and B and placed together in periodic table.
- The elements of sub group A are called Main or Representative Elements.
- The elements of sub group B are called Transition Elements. The group number indicate total number of electrons in valence shell of the element.
- The atomic size increases down a group but decreases along the period.
- Ionization energy decreases down a group but increases along a period.
- Electronegativity decreases down a group but increases along a period.
- Electron affinity decreases down a group but increases along a period.
- The Shielding effect increases down the group in periodic table and remain same in period from left to right.

EXERCISE

SECTION- A: MULTIPLE CHOICE QUESTIONS

Tick Mark (✓) the correct answer

1. In 1869 Mandeleev put forward his periodic law about:

   (a) Atomic Number (b) Chemical properties

   (c) Physical properties (d) Atomic Mass

2. The periodic table divided into s, p, d, and f block based on.

   (a) Atomic Radius (b) Electronic Configuration

   (c) Ionization Energy (d) Electron Affinity

3. 4th and 5th period in periodic table are known as:

(a) Short period (b) Long period

(c) Normal period (d) Very long period

4. Which one of the following decreases along the period?

(a) Ionization Energy (b) Atomic Radius

(c) Electronegativity (d) Electron Affinity

5. The elements of VIIA group are known as:

(a) Lanthanides (b) Actinides

(c) Halogens (d) Nobel Gases

6. According to Mosely the chemical properties of elements are the periodic function of their :

(a) Atomic Size (b) Atomic Mass

(c) Atomic Radius (d) Atomic Number

7. The shielding effect across the period :

(a) Increases (b) Decrease

(c) Moderate (d) Same

8. The ability to attract shared pair of electron is called:

(a) Electron Affinity (b) Electronegativity

(c) Ionization Energy (d) Shielding Effect

9. In group electron affinity values decreases from top to bottom because :

(a) Atomic size normal (b) Atomic size increases

(c) Atomic size decreases (d) Atomic size same

10. All Transition Elements are :

(a) Gases (b) Metals

(c) Nonmetals (d) Metalloids

SECTION- B: SHORT QUESTIONS:

1. Distinguish between periods and groups.
2. Describe the trend of electronegativity within group and period with the help of examples?
3. Explain the similarity of chemical and physical properties of elements in the same family.
4. Justify that periodicity of properties dependent upon number of protons in an atom?
5. Identify that which halogens exist as gases, liquid and solid?
6. Why Alkaline earth metals shows irregular melting and boiling point?
7. Why ionization energy, electron affinity and electronegativity exhibit same trend in period and groups?

SECTION- C: DETAILED QUESTIONS:

1. Discuss in detail the long form of periodic table.
2. Determine the demarcation of periodic table in to s, p, d and f blocks.
3. Identify the electronic configuration of the following elements.

   Na, Ca, F, Si
4. Determine the location of families on periodic table.
5. Discuss that Mendlevee periodic law provide a base for modern periodic table.
6. Explain how shielding effect influence the periodic trends?