PERIODIC CLASSIFICATION OF ELEMENTS

CONTENTS

Introduction

One hundred and fifteen elements are known till date and many more may be known in future. All elements differ in their properties due to the presence of different kinds of atoms in them. Elements combine to form millions of compounds.

Important Terms and Concepts :

1. **Need of Classification :** It is difficult to study each and every element individually and to know its properties and uses. Therefore, they have been classified into groups on the basis of their similarities in properties.
2. **Classification :** Classification means grouping of elements on the basis of similarities in properties, e.g., All of you belong to class X because you resemble in you properties, e.g., All of you have passed class IX, all of you are in age group of 13-15 years.
3. **Basis of Classification :** Classification is done on the basis of similarities in properties so that the systematic study could be made about them

Early attempts of classification

Lavoisier's Classification :

Lavoisier classified elements into metals and nonmetals. This classification was based on certain distinctive physical properties such as hardness, malleability and luster. On the basis of these properties, sodium and lead were classed together as belonging to the group of metals.

Limitations

(1) Hardness, malleability and luster were found to be the only common properties of sodium and lead, otherwise the two elements were entirely different.

(2) In such a classification there was no place for elements with properties resembling those of metals as well as nonmetals.

There fore, Lavoisier's classification was found to be inadequate.

Dobereiner's Classification :

Law of triads In 1817, German chemist Johann Dobereginer classified elements having similar chemical properties into groups of three. These groups were called triads. He proposed a law known as Dobereiner's law of triads. According to this law, when elements are arranged in the order of increasing atomic mass in a triad, the atomic mass of the middle element was found to be approximately equal to the arithmetic mean of the atomic masses of the other two elements.

Set I		Set II		Set-III	
Element	Atomic mass	Element	Atomic mass	Element	Atomic mass
Calcium	40	Lithium	7	Chlorine	35.5
Strontium	87.5	Sodium	23	Bromine	80
Barium	137	Potassium	39	Iodine	127
Average of the atomic masses of calcium and barium $=\frac{40+137}{2}=88.5$		Average of the atomic masses of lithium and potassium $=\frac{7+39}{2}=23$		Average of the atomic masses of chlorine and iodine $=\frac{35.5+127}{2}=81.2$	
Atomic mass of strontium = 87.5		Atomic mass of sodium = 23		Atomic mass of bromine = 80	

The classification of elements into triads was very successful in predicting the atomic mass and properties of the middle element. Further, this classification showed that there exists some relationship between the properties of elements and their atomic masses. This paved the way for future attempts at classification of elements.

Limitation : All the elements could not be grouped into triads.

◈ **Newlands' Classification :**

Law of octaves In 1864, John Newlands, and English chemist, showed that when elements are arranged in the order of their increasing atomic masses, the eighth element, starting from a given element, was a kind of repetition of the first one, like the eighth note in an octave of music, i.e.,

sa re ga ma pa dha ni sa,

where the first and the eighth note are same.

A part of Newlands' classification is given below where the figures under the symbols show the atomic masses

Octaves of music and Newlands' arrangement of elements

Indian :	sa	re	ga	ma	pa	dha	ni
Octaves	sa						
Western :	do	re	mi	fa	so	la	ti
	do						
Newlands's	H	Li	Be	B	C	N	O
arrangement of	1.0	7.0	9.0	11.0	12.0	14.0	16.0
elements with	F	Na	Mg	Al	Si	P	S
atomic masses	19.0	23.0	24.0	27.0	28.0	31.0	32.0
	Cl	K	Ca	Cr	Ti	Mn	Fe
	35.5	39.0	40.0	52.0	48.0	55.0	56.0
	Co and Ni	Cu	Zn	Y	In	As	Se
	58.93 and 58.71	63.54	65.37	88.90	114.82	74.92	78.96
	Br	Rb	Sr	Ce and La	Zr	—	—
	79.90	85.47	87.62	140.12 and 138.91	91.22		

Starting from lithium (Li) the eight element is sodium (Na). The eight element starting from sodium is potassium. The properties of lithium, sodium and potassium are similar. The properties of beryllium, magnesium and calcium are similar too.

Limitation :

(i) This law worked well for lighter elements (up to calcium), but it could not be applied to heavier ones (elements of higher atomic masses) because starting from calcium every eight element was found to have properties different from those of the first element.

(ii) Newlands emphatically said that only 56 elements do exist in nature and no more element is likely to be discovered in future. But this concept was later on found to be untrue with the discovery of many new elements which defined the law of octaves.

(iii) In arranging elements in the form of a table, Newlands clubbed two elements together at the same place and in the same column. Not only this, he also placed some dissimilar elements in the same column. For example, cobalt (Co) and nickel (Ni) were clubbed together in the column of fluorine (F), chlorine (Cl) and bromine (Br) (under sa/do). We know that cobalt and nickel have properties entirely different from those of fluorine, chlorine and bromine. It is also known that cobalt and nickel have properties similar to those of iron. But iron (Fe) was placed in a column (under ni/ti) different from the column of cobalt and nickel.

However, this law support to the idea that the properties of elements depend upon the atomic masses. It also showed that the properties of elements are repeated after a certain interval, i.e., the properties of elements are periodic in nature.

➢ Mendeleev's periodic law and periodic table

While working systematically on the physical and chemical properties of elements, Dmitri Invanovich Mendeleev noticed that properties of elements varied regularly with the atomic mass. He arranged the 63 elements then known in a table on the basis of similarities in properties. It was found that most of the elements occupied places in the table in order of their increasing atomic masses. In 1869, *Mendeleeve* formulated a law, now known as the periodic law. The law is stated as follows.

The properties of elements are periodic functions of their atomic masses. This means, *if the elements are arranged in order of increasing atomic masses then those with similar properties are repeated at regular intervals.*

On the basis of the periodic law, Mendeleev presented his classification in the form of a table, now known as *Mendeleev's periodic table.* A simplified version of this periodic table is given below. In this table, copper, silver and gold find places in groups I as well as VIII.

Groups → Periods↓	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**			
1	H 1										
2	Li 7	Be 9.4	B 11	C 12	N 14	O 16	F 19				
3	Na 23	Mg 24	Al 27.3	Si 28	P 31	S 32	Cl 35.5				
4	K 39	Ca 40	?	Ti 48	V 51	Cr 52	Mn 55	Fr 56	Co 59	Ni 59	Cu 63
5	Cu 63	Zn 65	? 68	? 72	As 75	Se 78	Br 80				
6	Rb 85	Sr 87	Yt 88	Zr 90	Nb 94	Mo 96	? 100	Ru 104	Rh 104	Pd 106	Ag 108
7	Ag 108	Cd 112	In 113	Sn 118	Sb 122	Te 125	I 127				
8	Cs	Ba	Di	Ce	?	?	?	?			

	133	137	138	140				
9	?	?	?	?	?	?	?	
10	?	?	Er 178	La 180	Ta 182	W 184	?	Os 195 Ir 197 Pt 198 Au 199
11	Au 199	Hg 200	Tl 204	Pb 207	Bi 208	?	?	
12	?	?	?	Th 231	?	U 240		

This table consists of vertical columns called groups and horizontal rows called periods. There are only eight groups in the table. Mendeleev left some vacant places (shown by question marks) for the yet undiscovered elements. Noble gases were not discovered then. So, he did not provide any place for them in his periodic table.

Mandeleev's idea was remarkable in that he used a fundamental atomic property (atomic mass) as the basis of classification. While classifying elements he laid special emphasis on tow factors.

1. Similar elements were grouped together.
2. Elements were arranged in order of increasing atomic masses.

◈ Modified version of Mendeleev's Periodic Table :

The elements which were undiscovered and for whom Mendeleev had left vacant places were discovered later. Some of these are scandium (Sc), gallium (Ga) and germanium (Ge). These elements were accommodated in their proper places in the table. The elements helium (He), neon (Ne), argon (Ar), Krypton (Kr), Xenon (Xe) and radon (Rn) became known only towards the end of the nineteenth century. These elements, called noble gases, were placed in the table as a separate group, called 0 group. The periodic table had to be modified then. The modified version of the table is shown below.

Group →	**I**		**II**		**III**		**IV**		**V**		**VI**		**VII**		**VIII**	**0**
Periods↓	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**		
1	H															He
2	Li		Be			B		C		N		O		F		Ne
3	Na		Mg			Al		Si		P		S		Cl		Ar
4	K	Cu	Ca	Zn	Sc	Ga	Ti	Ge	V	As	Cr	Se	Mn	Br	Fe Co Ni	Kr
5	Rb	Ag	Sr	Cd	Y	In	Zr	Sn	Nb	Sb	Mo	Te	Tc	I	Ru Rh Pd	Xe
6	Cs	Au	Ba	Hg	La*	Tl	Hf	Pb	Ta	Bi	W	Po	Re	At	Os Ir Pt	Rn
7	Fr		Ra		Ac**											

Lanthanide series* (along with langhanum)	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Actinide series (along with actinium)**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

◈ Features of the modified version of Mendeleev's periodic table :

1. **Groups into subgroups :** Each group of this periodic table is further divided into two subgroups A and B. The properties of

elements within a subgroup resemble more markedly but they differ from those of the elements of the other subgroups. For example., lithium (Li), sodium (Na), potassium (K), etc., of subgroups IA have close resemblance of properties but they have hardly any resemblance to the coinage metals (Cu, Ag and Au) of subgroup IB.

Mendeleev allowed the subgroups to be represented within the same group.

2. **Prediction of errors :** This periodic table could predict errors in the atomic masses of some elements on the basis of their position in the periodic table. For example, when the periodic table was published, the experimental value of the atomic mass of beryllium (Be) we was supposed to be 13.65 and its valency, 3. So, the position of Be should have been somewhere else, but Mendeleev placed it at its appropriate position on the basis of its properties. He further suggested that the atomic mass of Be needed correction. Mendeleev predicted its atomic mass to be 9.1 and valency, 2. Latter investigations proved him right.

   Similarly, the atomic mass of uranium was corrected from 120 to 240. Corrections were also made in the atomic masses of gold, platinum, etc.

3. Predictions of properties of higher to undiscovered element : We know that Mendeleev classified the elements in order of their increasing atomic masses. However, this order had to be ignored at some places to make sure that the elements with similar properties fell in the same group. In doing so, he left some vacant places in the table. These vacant places were kept reserved for elements not discovered till then. Mendeleev was confident that these elements would be discovered later and they would occupy these vacant places. Not only this, he also predicted the properties of these undiscovered elements on the basis of this study of his the properties of the neighboring elements. Amazingly, when the missing elements of Mendeleev's periodic table were discovered subsequently, their properties were found to be very similar to those predicted by Mendeleev.

   The elements scandium, gallium and germanium were not known in 1871 but their existence was predicted by mendelev. He named these elements as eka-boron, eka-Aluminium and eka silicon when these elements were discovered, they were named scandium, gallium and germanium respectively and their properties were found to be in good agreement with those predicted by Mendeleev. Properties of ka-aluminium (predicted by Mendeleev) and those of the gallium (discovered later) are given in table.

Property	**Eka-aluminium**	**Gallium**
Atomic mass	68	69.7
Formula of oxide	E_2O_3	Ga_2O_3
Formula of chloride	ECl_3	$GaCl_3$

   Considering its atomic mass, titanium (Ti) should have been placed below aluminium in the periodic table, but Mendeleev placed is below silicon (Si) because the properties of titanium were similar to those of silicon. Thus, a gap was left below aluminium in the periodic table. This gap was filled up by gallium which was discovered later. The properties of gallium (Ga) were found to be similar to those of boron and aluminium.

4. **Basic features intact :** All the basic features of Mendeleev's periodic table are intact even today. Even when a new class of elements, i.e., noble gases, were discovered, they found place in a separate group called the zero group. The existing order of the periodic table was not at all disturbed.

❖ Discrepancies in Mendeleev's periodic table :

Mendeleev's periodic table has the following defects.

1. **Position of hydrogen :** The position of hydrogen in the periodic table is anomalous. Hydrogen resembles alkali metals (Li, Na, K, etc). So it may be placed in the group of the halogens (VII A).
2. **Position of lanthanides and actinides :** The elements from atomic number 57 to 71 are collectively known as lanthanides. They do

not have a proper place in the periodic table. They all have been placed at the same position in group III and period 6. Similarly, the actinides (atomic numbers 89-103) also have no proper place in the periodic table. These elements have also been placed in the same position, in group III and period 7.

3. **Some similar elements are separated, while some dissimilar elements have been placed in the group :** Some similar elements are separated in the periodic table. For example, copper (Cu) and mercury (Hg), silver (Ag) and thallium (Tl), and barium (Ba) and lead (Pb). On the other hand, some dissimilar elements have been placed together in the same group. For example, copper (Cu), silver (Ag) and gold (Au) have been placed in group I along with the alkali metals. Similarly, manganese (Mn) is placed in the group of the halogens.

4. **Presence of some anomalous pairs of elements :** In Mendeleev's periodic table, elements are arranged in order of increasing atomic mass. In some places, this order has been ignored.
   (a) The atomic mass of argon is 40 and that of potassium is 39. But argon is placed before potassium in the periodic table.
   (b) The positions of cobalt and nickel are not in proper order. Cobalt (at. mass = 58.9) is placed before nickel (at. mass = 58.6).
   (c) Tellurium (at. mass = 127.6) is placed before iodine (at. mass = 126.9).
   (d) Thorium (at. mass = 232.12) is placed before protactinium (at. mass = 231)

5. **Position of isotopes :** The isotopes of an element have no place in the periodic table.

The failure of Mendeleev's periodic law to explain the wrong order of the atomic masses of some elements and the position of isotopes led scientists working in this field to conclude that atomic mass cannot be the basis for the classification of elements. There must be a more fundamental property of elements which can be the basis of classification.

Anomalous pairs of elements

Element →	Ar	K	Co	Ni	Te	I	Th	Pa
Atomic mass	40	39	59.9	58.6	127.6	126.9	232.12	231
Group	0	IA	VIII	VIII	VI B	VII B	III B	III B

❖ **Modern Periodic Table :**

Henry Moseley, an English physicist found that the atomic number (Z) was the fundamental property of an elements and not the atomic mass for classification of elements.

❖ **Modern Periodic Law :**

''Properties of elements are periodic functions of their atomic numbers, i.e., the number of protons or electrons present in the neutral atom of an element.''

❖ **Long form of Periodic Table :**

Arranged in increasing order of their atomic numbers.

The prediction of properties elements and their compounds can be made with precision. All drawbacks of Mendeleev's Periodic Table vanish when the elements are arranged on the basis of increasing atomic numbers.

❖ **Elements in a Group :**

(1) They show similar chemical properties due to similar outer electronic configuration, i.e., same number of valence electrons.

(2) They have gradation in properties due to gradually varying attraction of the nucleus and the outer valence electrons as we go down the group.

◈ **Main Features of the Long Form of the Periodic Table :**

(1) It shows arrangement of elements based on modern periodic law.

(2) There are 18 vertical columns known as groups.

(3) There are 7 horizontal rows known as periods.

(4) Elements having similar outer electronic configurations, i.e., having same valence electrons have been placed in same groups, e.g.,

Group-1

		K	L	M	N	O	P	Q
H	(1)	1						
Li	(3)	2,	1					
Na	(11)	2,	8,	1				
K	(19)	2,	8,	8,	1			
Rb	(37)	2,	8,	18,	8,	1		
Cs	(55)	2,	8,	18,	18,	8,	1	
Fr	(87)	2,	8,	18,	32,	18,	8,	1

Group-2

		K	L	M	N	O	P	Q
Be	(4)	2	2					
Mg	(12)	2,	8,	2				
Ca	(20)	2,	8,	8,	2			
Sr	(38)	2,	8,	18,	8,	2		
Ba	(56)	2,	8,	18,	18,	8,	2	
Ra	(88)	2,	8,	18,	32,	18,	8,	2

Group-13

		K	L	M	N	O	P
B	(5)	2	3				
Al	(13)	2,	8,	3			
Ga	(31)	2,	8,	18,	3		
In	(49)	2,	8,	18,	18,	3	
Tl	(81)	2,	8,	18,	32,	18,	3

Group-14

		K	L	M	N	O	P
C	(6)	2	4				
Si	(14)	2,	8,	4			
Ge	(32)	2,	8,	18,	4		
Sn	(50)	2,	8,	18,	18,	4	
Pb	(82)	2,	8,	18,	32,	18,	4

Group-15

		K	L	M	N	O	P
N	(7)	2	5				
P	(15)	2,	8,	5			
As	(33)	2,	8,	18,	5		
Sb	(51)	2,	8,	18,	18,	5	
Bi	(83)	2,	8,	18,	32,	18,	5

Group-16

		K	L	M	N	O	P
O	(8)	2	6				
S	(16)	2,	8,	6			

Se	(34)	2,	8,	18,	6		
Te	(52)	2,	8,	18,	18,	6	
Po	(84)	2,	8,	18,	32,	18,	6

Group-17

		K	L	M	N	O	P
F	(9)	2	7				
Cl	(17)	2,	8,	7			
Br	(35)	2,	8,	18,	7		
I	(53)	2,	8,	18,	18,	7	
At	(85)	2,	8,	18,	32,	18,	7

Group-18

		K	L	M	N	O	P
He	(2)	2					
Ne	(10)	2,	8				
Ar	(18)	2,	8,	8			
Kr	(36)	2,	8,	18,	8		
Xe	(54)	2,	8,	18,	18,	8	
Rn	(86)	2,	8,	18,	32,	18,	8

(5) In periods, elements in which the number of electrons in the outermost shell increases gradually in step one are placed, e.g.,

Period 1 (K-shell)	H 1							He 2
Second Period (K, L, shells)	Li(3) 2, 1	Be(4) 2, 2	B(5) 2, 3	C(6) 2, 4	N(7) 2, 5	O(8) 2, 6	F(9) 2, 7	Ne(10) 2, 8

(6) Each group in the table signifies identical outer shell electronic configuration i.e., same valence electrons, e.g., group 1 has 1 valence electron, group 2 has 2 valence electrons, group 13 has 3, group 14 has 4 valence electrons.

(7) Each period starts with filling of new shell, e.g.,

1^{st} Period – K shell (1^{st} shell) starts filling with Hydrogen and ends at Helium.

2^{nd} Period – L shell (2^{nd} shell) starts filling from Li (3) upto Ne (10)

3^{rd} Period – M shell (3^{rd} shell) start filling from Na (11) upto Ar (18)

4^{th} Period – N shell (4^{th} shell) starts filling from K (19) upto Kr (36) and so on.

(8) The periodic table is divided in four blocks :

(a) s-block elements : Group 1 and 2 elements are called s-block elements.

(b) p-block elements : Group 13 to 18 elements are called p-block elements

(c) d-block elements : Group 3 to group 12 are called d-block elements or transition elements (in between s- block and p-block elements)

(d) f-block elements : The elements placed at the bottom of the periodic table are known as f-block elements. The fourteen elements after La(57) (Lanthanum) are called Lanthanoides and 14 elements after Actinium Ac (89) are called Actinoides.

◈ Naturally occurring Elements :

Elements upto atomic number 92 occur in nature except Technetium, Tc (Z = 43) and Promethium, Pm (Z = 61) which are formed from radioactive elements where 'Z' represents atomic number.

Synthetic Elements : Elements beyond atomic number 92 are man-made elements. They are also called synthetic elements

Groups :

(1) Elements in a group have same number of valence electrons.

(2) The chemical properties of valence electrons, e.g., all the group 1 elements have 1 valence electron. They form positively charged ions by losing one electron, when required amount of energy is supplied to them i.e., Li^+, Na^+, K^+.

Group 1 elements are called alkali metals. Group 2 elements are called alkaline earth metals.

Group 2 elements when 2 valence electrons in the outermost shells. They can lose both the valence electrons to form dipositive cations, i.e., Be^{2+}, Mg^{2+}, Ca^{2+}, etc. Positively charged ions are called cations.

Group 13 elements belong to boron family, 14 to carbon family, 15 to Nitrogen family, 16 to Oxygen family.

Group 16 elements contain 6 valence electrons in their outermost shells, i.e., two electrons less than the maximum number of electrons that can be present in the outermost shell. They can gain 2 electrons more easily rather than lose 6 electrons. They change into dinegative ions such as O^{2-}, S^{2-}. Group 17 elements called Halogens contain 7 valence electrons. They can gain one electron to acquire stable electronic configuration, i.e., 8 electrons in the outermost shell and form uni-negative (single negative) ions such as F^-, Cl^-, Br^-, I^-.

Negatively charged ions are called anions.

Group 18 elements called noble gases, have their outermost, shell completely filled. The elements of this group have no tendency to lose or gain electrons. Thus, the elements of this group have zero valency and are almost unreactive. Hence they are called Noble gases. However, nowadays, compounds of Kr, Xe and Rn have been prepared.

In any particular group, the number of shells increase but the number of valence electrons remains the same.

◈ Periods :

(1) The horizontal rows in the periodic table are called periods.

(2) There are 7 periods in the long form of periodic table

(3) The first period contains 2 elements, Hydrogen and Helium. They have only one shell.

(4) The second period contains 8 elements : Lithium Li(3), Beryllium Be(4), Boron B(5), Carbon C(6), Nitrogen N(7), Oxygen O (8), Fluorine F(9) and Neon Ne (10). The second period has 2 shells (K and L) and L shell is progressive filled.

(v) The elements of 3rd period are :

3rd Period	Na (11)	Mg (12)	Al (13)	Si (14)	P (15)	S (16)	Cl (17)	Ar (18)
(K, L, M shells)	2, 8, 1	2, 3, 2	2, 8, 3	2, 8, 4	2, 8, 5	2, 8, 6	2, 8, 7	2, 8, 8

In 3rd period, 3rd shell (M-shell) is being progressively filled and there are three shells.

4th period has 18 elements

5th period has 18 elements

6th period has 32 elements

7th period has 32 elements

In periods, the number of valence electrons increases from left to right in s and p-blocks s-Block Elements | d-Block Elements | p-Block Elements

Metals | Non metals | Metalloids | Noble gases

Group → Period ↓	IA (1)	IIA (2)	IIIB (3)	IVB (4)	VB (5)	VIB (6)	VIIB (7)	VIII (8)	VIII (9)	VIII (10)	IB (11)	IIB (12)	IIIA (13)	IVA (14)	VA (15)	VIA (16)	VIIA (17)	0 (18)
1	1 H 1.0079 Hydrogen																	2 He 4.0026 Helium
2	3 Li 6.940 Lithium	4 Be 9.0122 Beryllium											5 B 10.811 Boron	6 C 12.011 Carbon	7 N 14.007 Nitrogen	8 O 15.999 Nitrogen	9 F 18.998 Fluonne	10 Ne 20.180 Neon
3	11 Na 22.990 Sodium	12 Mg 24.305 Magnesium											13 Al 6.982 Aluminium	14 Si 28.086 Silicon	15 P 30.974 Phosporus	16 S 32.066 Sulphur	17 Cl 35.453 Chlorine	18 Ar 39.948 Argon
4	19 K 39.098 Potassium	20 Ca 40.078 Calcium	21 Sc 44.956 Scandium	22 Ti 47.867 Titanium	23 V 50.941 Vanadium	24 Cr 51.996 Chrominum	25 Mn 54.938 Magnanese	26 Fe 55.847 Iron	27 Co 58.933 Cobolt	28 Ni 58.693 Nickel	29 Cu 63.546 Copper	30 Zn 65.39 Zinc	31 Ga 62.723 Gallium	32 Ge 72.61 Germanium	33 As 74.922 Arsenic	34 Se 78.96 Selenium	35 Br 79.904 Bromine	36 Kr 83.80 Krypton
5	37 Rb 85.468 Rubidium	38 Sr 87.62 Strontium	39 Y 88.936 Yttrium	40 Zr 91.224 Zirconium	41 Nb 92.906 Molybdenum	42 Mo 95.94 Molybdenum	43 Tc 98 Technetium	44 Ru 101.07 Ruthenium	45 Rh 102.91 Rhodium	46 Pd 106.42 Palladium	47 Ag 107.87 Silver	48 Cd 112.41 Cadmium	49 In 114.82 Indium	50 Sn 118.71 Tin	51 Sb 121.76 Arsenic	52 Te 127.60 Tellurium	53 I 126.90 Iodine	54 Xe 131.29 Xenon
6	55 Cs 132.91 Cesium	56 Ba 137.33 Barium	57 La* 138.91 Lanthanum	72 Hf 178.49 Hafnium	73 Ta 180.95 Tantalum	74 W 183.84 Tungsten	75 Re 186.21 Rhenium	76 Os 190.23 Osmium	77 Ir 192.22 Iridium	78 Pt 195.08 Platinum	79 Au 196.97 Gold	80 Hg 200.59 Mercury	81 Ti 204.59 Thallium	82 Pb 207.2 Lead	83 Bi 208.98 Bismuth	84 Po 210 Polonium	85 At 210 Astatine	86 Rn 222 Radon
7	87 Fr 223 Francium	88 Ra 226 Radium	89 Ac** 227 Actinium	104 Unq 261 Unnilquadium	105 Unp 262 Unnilpentium	106 Unh 266 Unnilhexium	107 Uns 264 Unnilseptium	108 Uno 269 Unniloctium	109 Une 268 Unnilennium	110 Uun 269 Ununnilium	111 Uuu 272 Unununium	112 Uub 277 Ununbium						

f-Block Elements

6	*Lanthanide Series	58 Ce 140.12 Cerium	59 Pr 140.91 Praseodymium	60 Nd 144.24 Neodymium	61 Pm 145 Promethium	62 Sm 150.36 Samarium	63 Eu 151.96 Europium	64 Gd 157.25 Gadolinium	65 Tb 158.93 Terbium	66 Dy 162.50 Dysprosium	67 Ho 164.93 Holmium	68 Er 167.26 Erbium	69 Tm 168.93 Thulium	70 Yb 173.07 Ytterbium	71 Lu 174.97 Lutetium
7	**Actinide Series	90 Th 232.04 Thorium	91 Pa 231.04 Protactinium	92 U 238.03 Uranium	93 Np 237 Neptunium	94 Pu 244 Prutonium	95 Am 243 Americium	96 Cm 247 Curium	97 Bk 247 Berkelium	98 Cf 251 Califonium	99 Es 252 Einsteinium	100 Fm 257 Fermium	101 Md 258 Mendelevium	102 No 259 Nobelium	103 Lr 262 Lawrencium

◈ Periodicity in Properties :

The properties of elements depends upon the electronic configuration which changes along a period and down a group in periodic table.

There is periodicity in properties, i.e., repetition of properties after a regular interval due to similarity in electronic configuration.

◈ Atomic Size (Atomic radii) :

Atomic size means radius of an atom. It is defined as distance between centre of nucleus and outermost shell (valence shell) of an isolated atoms.

◈ Covalent Radii :

It is defined as half of the distance between the centres of nuclei of two atoms (bond length) bonded by a single covalent bond, e.g., Bond length in case of H—H (Hydrogen molecule) is 74 pm.

Covalent radius = 1/2 × 74 pm = 37 pm (picometre)

$$[1 \text{ pm} = 10^{-12} \text{ m}]$$

It can be measured in case of diatomic molecules of non-metals.

◈ **Metallic Radii :** If is defined as half of the internuclear distance between the two metal ions in a metallic crystal. It is measured in case of metals.

◈ Variation of Atomic size in a Group :

Size generally increases from top to bottom in a group.

Reason : It is due to addition of a new shell, i.e., number of shells go one increasing, e.g., pm stands for picometre, i.e., 10^{-12} m.

Group I	Electronic Configuration	No. of Shells	Atomic radius (pm)
Li(3)	2, 1	(2 shells)	133
Na(11)	2, 8, 1	(3 shells)	154
K(19)	2, 8, 8, 1	(4 shells)	201
Rb(37)	2, 8, 18, 8, 1	(5 shells)	216
Cs(55)	2, 8, 18, 18, 8, 1	(6 shells)	235

◈ Variation of Atomic size along a Period :

Atomic size goes on decreasing along a period from left to right

Reason : It is due to increase in nuclear charge (number of protons in nucleus) which pulls the electrons towards it, i.e., force of attraction between nucleus and valence electrons increase, therefore atomic size decreases, e.g.,

Elements of 2nd Period Atomic radius (pm)	Elements of 3rd Period Atomic radius (pm)	
Li (3) 133	Na(11) 154	
Be(4) 89	Mg(12) 136	

B(5) 80	Al(13) 125	
C(6) 77	Si(14) 117	
N(7) 70	P(15) 110	
O(8) 66	S(16) 104	
F(9) 64	Cl(17) 99	

◈ Ionisation Energy and Electron Affinity :

Chemical nature and reactivity of an element depend upon the ability of its atoms to donate or accept electrons. This can be measured quantitatively with the help of ionisation energy and electron affinity of its atoms :

Ionisation energy : It is defined as the energy required to remove an electron completely from an isolated gaseous atom of an element. The energy required to remove the 1st electron is called first ionisation energy.

$$A(g) + I.E_1 \longrightarrow A^+(g) + e^-$$

◈ Second Ionisation Energy : he energy required to remove an electron from a unipositive ion is called the second ionisation energy.

$$A^+(g) + I.E_2 \longrightarrow A^{2+}(g) + e^-$$

Te second ionisation energy is greater than the first ionisation energy due to increase in positive charge, hence increase in force of attraction between the nucleus and the valence electron.

$$\text{Ist I.E.} < 2^{nd}\ \text{I.E.} < 3^{rd}\ \text{I.E.}$$

◈ Variation of Ionisation energy down a Group :

Ionisation energy goes on decreasing down a group.

Reason : It is due to the increase in the distance between the valence electrons and the nucleus as the atomic size increase down a group, the force of attraction between the nucleus and the valence electrons decrease, therefore, the energy required to remove the electrons, i.e., the ioisation energy goes on decreasing

Example :

Group I	**Ionisation Energy (in kJ mol^{-1})**	**Group 2**	**Second Ionisation Energy (in kJ mol^{-1})**	**First Ionisation Energy (in kJ mol^{-1})**
Li	500	Be	1757	899
Na	496	Mg	1450	737
K	420	Ca	1146	590
Rb	403	Sr	1064	549
Cs	376	Ba	965	503

◈ Variation of Ionisation energy along a Period :

It goes on increasing generally along a period from left to right with decrease in atomic size.

Reason : Due to decrease in atomic size, the force of attraction between the valence electrons and the nucleus increase and, therefore, more energy is required to remove electron.

Example :

Elements of 2nd Period	**I.E. in kJ mol^{-1}**
Li	500

Be	900
B	801
C	1085
N	1400
O	1314
F	1680
Ne	2080

There is a decrease in ionisation energy from Be to B and from N to O, the reason of which you will study in higher classes.

Group 18 elements (noble gases) have the highest ionisation energy in respective periods due to stable electronic configuration, i.e., 8 electrons in their valence shells except He which has 2 electrons.

◈ Electron Affinity :

It is the energy change when an electron is gained by a neutral gaseous atom converting it into a negatively charged ion.

It is a measure of attraction or affinity of the gaseous atom for an extra electron to be added.

$$Cl(g) + e^- \longrightarrow Cl^-(g) + E.A.$$

◈ Factors :

It depends upon atomic size as well as *electronic configuration.*

◈ Variation down the Group :

Electron affinity goes on decreasing down the group in general.

Reason : Due to the increase in atomic size, the force of attraction between the nucleus and the electron to e added becomes less.

◈ Variation along a Period :

Electron affinity increase from left to right in period.

Reason : It is due to decrease in atomic size which leads to an increase in the force of attraction between the nucleus and the electrons to be added.

Example :

Group 17	E.A. (kJ mol^{-1})
F	333
Cl	348
Br	324
I	295

However, deviations to this rule are observed in variation of electron affinity.

◈ Metallic and Non-metallic Character :

Group 1 to 12 are metals. Group 13 to 18 comprise non-metals, metalloids and metals.

Metalloids : Those elements which resemble both metals and non-metals are called metalloids. They are also called semi-metals, e.g., Boron, Silicon, Germinaium, Arsenic, Antimony, Tellurium and Polonium.

Properties of Metals :

(i) The are malleable.

(ii) They are ductile.

(iii) They are good conductors of heat and electricity.

(iv) They have generally 1 to 3 valence electrons.

(v) They have the same or less number of electrons in their outermost shell than the number of shells.

(vi) They are mostly solids.

Properties of Non-metals :

(i) They exist in solid, liquid or gaseous state.

(ii) Non-metals are generally brittle.

(iii) They are non conductors.

(iv) They have 4 to 8 valence electrons.

- **Variation of Metallic Character :**

Metallic character increases down a group due to decrease in ionisation energy. It decrease along a period due to increase in ionisation energy from left to right

- **Variation of Non-metallic Character :**

Non-metallic character decreases down a group because of decrease in electron affinity which is due to increase in atomic size.

Along a period, non-metallic character increases from left to right due to increase in electron affinity which is due to decrease in atomic size

POINTS TO REMEMBER

- Dobereiner's law of triads states that in a given set of three elements (triad) the atomic mass of the middle element is approximately equal to the average of the atomic masses of the other two elements.
- Newland's law of octaves states that if the elements are arranged in order of increasing atomic mass, the eighth element starting from a given element shows a repetition of the properties of the first element.
- According to Mendeleev's periodic law, the physical and chemical properties of elements are a periodic function of their atomic masses.
- Mendeleev's periodic table (i) helped correct the wrongly assigned values of atomic masses of some elements, and (ii) predicted the properties of some undiscovered elements.
- In Mendeleev's periodic table (i) isotopes had no place, and (ii) some similar elements are separated, while some dissimilar elements are placed in the same group.
- In Mendeleev's periodic table there are eight groups (I to VIII). Each group is divided into subgroups A and B, except group VIII. In the modern periodic table there are 18 groups.
- The vertical columns of the periodic table are called groups.
- The horizontal rows of the periodic table are called periods.
- Modern periodic law. The physical and chemical properties of elements are a periodic function of their atomic numbers.
- The modern periodic table (long form) is based on atomic number.
- There are seven periods in the periodic table. The first six periods consists of 2, 8, 8, 18, 18 and 32 elements respectively. The seventh periods is still incomplete.
- Elements in a group have similar properties.

- The regular occurrence of similar chemical properties of elements with increasing atomic number is known as chemical periodicity.
- A series of transition elements starting from actinium are called actinides or actinoids.
- A family of elements headed by helium in the periodic table constitutes the noble gases. They are unrecactive.
- An element that is intermediate between metals and nonmetals is known as a metalloid.
- The elements of group 1 are called alkali metals.
- The elements of group 2 are called alkaline earth metals.