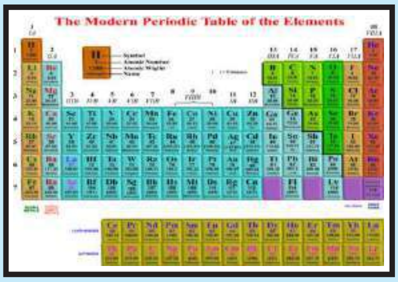
Chapter

9

Classification of Elements- The Periodic Table



A medical shop contains a vast number of medicines. The shop keeper finds difficult or impossible to remember all the names of medicines that he has. When you go to a medical shop and ask the shopkeeper for a particular medicine, he hands over it to you without any difficulty. How is it possible?

Think of a super bazaar. When you step inside you see a particular arrangement of goods inside it. When you look for grocery that you need, you go to it and select what you want. In what way it makes your selection easy?

From the above observations you understand that for any system involving several things, a particular order of arrangement of those things is essential.

Even in chemistry, from the earliest times, scientists have been trying to classify the available elements on the basis of their properties.

Need for the arrangement of elements in an organised manner

Robert Boyle (1661) defined an element as any substance that cannot be decomposed into a further simple substance by a physical or chemical change.

At his time, about thirteen elements were known.

Towards the end of the eighteenth century, by the time of Lavoisier another eleven elements were discovered. By 1865 about sixty three elements were known and by 1940, a total of ninety one elements from natural sources and another seventeen elements synthetically were obtained.

By now, including synthetic elements, there are more than 115 elements. As the number of elements increased, it became difficult to keep in memory the chemistries of individual elements and their compounds.

In previous classes we learnt that elements were classified into metals and non-metals. But this classification had so many limitations. So, there was a need to classify them in other ways. Hence, chemists started to frame ways to group these elements and compounds on the basis of their physical and chemical properties.

In the beginning of the 18th century Joseph Louis Proust stated that hydrogen atom is the building material and atoms of all other elements are simply due to the combination of number of hydrogen atoms. (It is to be noted that at his time the atomic weights of all elements were given as whole numbers and the atomic weight of hydrogen was taken as one.)

Dobereiner's law of Triads

A German chemist Johann Wolfgang Döbereiner (1829) noted that there were groups of elements with three elements known as *triads* in each group with similar chemical properties. He tried to give a relationship between the properties of elments and their atomic weights.

Döbereiner stated that when elements with similar properties are taken three at a time and arranged in the ascending order of their atomic weights, the atomic weight of the middle element is the average of the atomic weights of the first and third elements. This statement is called the Dobereiner's *law of triads*.

Activity 1

Observe the following table.

Elements in each row represent a triad.

Group	Elements and their Atomic weight			Arithmetic mean of Atomic weight
A	Lithium (Li) 7.0	Sodium (Na) 23.0	Potassium (K) 39.0	$\frac{7.0 + 39.0}{2} = 23.0$
B	Calcium (Ca) 40.0	Strontium(Sr) 87.5	Barium (Ba) 137.0	
C	Chlorine (C*l*) 35.5	Bromine (Br) 80.0	Iodine (I) 127.0	
D	Sulphur (S) 32.0	Selenium (Se) 78.0	Tellurium (Te) 125.0	
E	Manganese(Mn) 55.0	Chromium(Cr) 52.0	Iron (Fe) 56.0	

In the first row you will find that atomic weight of sodium (Na) is equal to the average of relative atomic weight of Li and K.

- Can you establish the same relationship with the set of elements given in the remaining rows?
- Find average atomic weights of the first and thired elements in each row and compare it with the atomic weight of the middle element.
- What do you observe?

Döbereiner's attempts gave a clue that atomic weights could be correlated with properties of elements. It made chemists look at elements in terms of groups of elements with similar chemical and physical properties. This eventually led to rigorous classification of elements and the modern periodic table of elements.

Limitations

i. All the known elements at that time could not be arranged in the form of triads.

ii. The law failed for very low mass or for very high mass elements.
In case of F, C*l*, Br, the atomic weight of C*l* is not an arithmetic mean of atomic weights of F and Br.

iii. As the techniques improved for measuring atomic masses accurately, the law was unable to remain strictly valid.

Think and discuss

- What relation about elements did Döbereiner want to establish?
- The densities of calcium (Ca) and barium (Ba) are 1.55 and 3.51 gcm^{-3} respectively. Based on Dobereiner's law of triads can you give the approximate density of strontium (Sr)?

Newlands' law of Octaves

John Newlands was a British chemist. Newlands (1865) found that when elements were arranged in the ascending order of their atomic weights they appeared to fall into seven groups. Each group contained elements with similar chemical properties. Based on these observations, Newlands proposed the law of octaves.

The law of octaves states that when elements are arranged in the ascending order of their atomic weights they fall into a pattern in which their properties repeat at regular intervals. Every eighth element starting from a given element resembles in its properties to that of the starting element.

Table 1: Newlands' table of elements.

Element	No.	Element	No.	Element	No.	Element	No.	Element	No.	Element	No.	Element	No.	Element	No.
H	1	F	8	Cl	15	Co&Ni	22	Br	29	Pd	36	I	42	Pt&Ir	50
Li	2	Na	9	K	16	Cu	23	Rb	30	Ag	37	Cs	44	Os	51
G	3	Mg	10	Ca	17	Zn	24	Sr	31	Cd	38	Ba&V	45	Hg	52
Bo	4	Al	11	Cr	19	Y	25	Ce&La	33	U	40	Ta	46	Tl	53
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Pb	54
N	6	P	13	Mn	20	As	27	Di&Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Ro&Ru	35	Te	43	Au	49	Th	56

Elements with similar chemical properties are to be present along a horizantal row.

Newlands was the first to assign atomic numbers to the elements. Unfortunately his work was neither accepted by his seniors nor by the journal of the Chemical society, which rejected its publication.

In Newlands' table of elements, if we start with hydrogen and move down and then start at the top the eighth element is fluorine and next eighth element is chlorine and so on. The properties hydrogen, fluorine and chlorine are similar.

Similarly, if you start at lithium, then eighth element is sodium and next coming eighth is potassium and so on. These elements show similar physical and chemical properties.

Think and discuss

- Do you know why Newlands proposed the law of octaves? Explain your answer in terms of the modern structure of the atom.
- Do you think that Newlands' law of octaves is correct? Justify

Newlands' table is not without problems.

- There are instances of two elements fitted into the same slot, e.g. cobalt and nickel.
- Certain elements, totally dissimilar in their properties, were fitted into the same group,

For example he arranged Co, Ni, Pd, Pt and Ir which have different properties compared with halogens in the same row (F, C*l*, Br, I). (see Newlands' first horizontal row)

It was found that the law of octaves holds good only for the elements up to calcium. The law was not valid for elements that had atomic masses higher than calcium.

Newlands periodic table was restricted to only 56 elements and did not leave any room for new elements. Elements that were discovered later could not be fitted into Newlands table in accordance with their properties.

Newlands attempted to link the periodicity of the chemical properties of elements with the periodicity found in the music. In musical scale any note in a key is separated from its octave by an interval of seven notes. This must have made him to force all the elements into this active pattern sometimes without caring the similarities.

Do you know?

Are you familiar with musical notes?

In the Indian system of music, there are seven musical notes in a scale – *sa, re ga, ma, pa, da, ni.* In the west, they use the notations - *do, re, mi, fa, so, la, ti.* Naturally, there must be some repetition of notes. Every eighth note is similar to the first one and it is the first note of the next scale.

Mendeleeff's Periodic Table

Mendeleeff arranged the elements known at that time in a chart in a systematic order in the increasing order of their atomic weights. He divided the chart into 8 vertical columns known as *groups*. Each group is divided into A, B sub groups. Each column contained elements of similar chemical properties.

The elements in the first column, for example, react with oxygen to form compounds with the general formula R_2O. For example, Li, Na and K when react with oxygen and form compounds Li_2O, Na_2O and K_2O respectively.

Elements of the second column react with oxygen to form compounds with the general formula RO. For example, Be, Mg and Ca when react with oxygen form BeO, MgO and CaO.

Mendeleeff tried to explain the similarities of elements in the same group in terms of their common valency.

The Periodic Law

Based on Mendeleeff's observations regarding the properties of elements in the periodic table, a law known as the *periodic law* of the properties of elements was proposed as follows.

The law states that the physical and chemical properties of the elements are a periodic function of their atomic weights.

Table-2 : Mendeleeff's Periodic Table (1871 version)

Reihen	Gruppe I. – R^2O	Gruppe II. – RO	Gruppe III. – R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2H^7	Gruppe VIII. —— RO^4
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	–=44	Ti=48	V=51	Cr=52	Mn=55	Fo=56, Co=59 Ni=59, Cu=63
5	(Cu=63)	Zn=65	–=68	–=72	As=75	So=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	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	–	–	–	– – – –
9	(–)	–	–	–	–	–	–	
10	–	–	?Ek=178	?La=180	Ta=182	W=184	–	Os=195, Ir=197, Pt=198, Au=199
11	(Au=198)	Hg=200	Tl=204	Pb=207	Bi=208	–	–	
12	–	–	–	Th=231	–	U=240	–	– – – –

Salient features and achievements of the Mendeleeff's periodic table

1. **Groups and sub-groups:** There are eight vertical columns in Mendeleeff's periodic table called as *groups*. They are represented by Roman numerals I to VIII. Elements present in a given vertical column (group) have similar properties. Each group is divided into two sub-groups 'A' and 'B'. The elements within any sub-group resemble one another to great a extent. For example, sub-group IA elements called 'alkali metals' (Li, Na, K, Rb, Cs, Fr) resemble each other very much in their properties.
2. **Periods:** The horizontal rows in Mendeleeff's periodic table are called *periods*. There are seven periods in the table, which are denoted by Arabic numerals 1 to 7. Elements in a period differ in their properties from one another. A period comprises the entire range of elements after which properties repeat themselves.

3. **Predicting the properties of missing elements:** Based on the arrangement of the elements in the table he predicted that some elements were missing and left blank spaces at the appropriate places in the table.

Mendeleeff believed that some new elements would be discovered definitely. He predicted the properties of these new additional elements in advance purely depending on his table. His predicted properties were almost the same as the observed properties of those elements after their discovery.

He named those elements tentatively by adding the prefix '***eka***' (*eka is a Sanskrit word for numeral one*) to the name of the element immediately above each empty space. The predicted properties of elements namely eka-boron, eka-aluminium and eka-silicon were close to the observed properties of scandium, gallium and germanium respectively which were discovered later.

S. No.	Property	Predicted property by Mendeleeff		Observed property	
		Eka-Aluminium (Ea)	Eka-Silicon (Es)	Gallium (1875)	Germanium (1886)
1	Atomic weight	68	72	69.72	72.59
2	Density	5.9	5..5	5.94	5.47
3	Formula of oxide	Ea_2O_3	EsO_2	Ga_2O_3	GeO_2
4	Formula of chloride	$EaCl_3$	$EsCl_4$	$GaCl_3$	$GeCl_4$

Do you know?

Do you know what Mendeleeff said about the melting point of *eka Al*?

'If I hold it in my hand, it will melt'. The melting point of Ga is 30.2°C and our body temprature 37°C.

4. **Correction of atomic weights:** The placement of elements in Mendeleeff's periodic table helped in correcting the atomic masses of some elements like, beryllium, indium and gold.

   For example, At the time of Mendeleeff, beryllium (Be) was given atomic weight 13.5.

   Atomic weight = equivalent weight × valency

   The equivalent weight of Be was found experimentally as 4.5 and its valency was thought as 3. Therefore, the atomic weight of beryllium was given as 4.5 × 3 = 13.5. With this atomic weight it had to be placed in a wrong group in the table. He said that its valency should be only 2. Then its atomic weight would be 4.5 × 2 = 9. If atomic weight of 'Be' is 9 it would be fit in the second group and its properties practically are similar to Mg, Ca etc., of the second group elements. He also helped in the calculation of the correct atomic weights of ‘Indium’ and ‘Gold’ in this manner.

5. **Anomalous series:** Some anomalous series of elements like ‘Te’ and ‘I’ were observed in the table. The anomalous series contained elements with more atomic weights like ‘Te’ (127.6 U) placed before the elements with less atomic weights like ‘I’ (126.9 U). Mendeleeff accepted minor inversions in the order of increasing atomic weights as these inversions resulted in elements being placed in the correct groups.

It was the extraordinary thinking of Mendeleeff that made the chemists to accept the periodic table and recognise Mendeleeff more than anyone else as the originator of the periodic law.

Do you know?

At the time when Mendeleeff introduced his periodic table even electrons were not discovered. Even then the periodic table was able to provide a scientific base for the study of chemistry of elements. In his honour the 101th element was named ***Mendelevium***.

Limitations of Mendeleeff’s periodic table

1. **Anomalous pair of elements:** Certain elements of highest atomic weights precede those with lower atomic weights.
   For example, *tellurium* (atomic weight 127.6) precedes *iodine* (atomic weight 126.9).
2. **Dissimilar elements placed together:** elements with dissimilar properties were placed in same group as sub-group A and sub-group B. For example, alkali metal like Li, Na, K etc., of IA group have little resemblance with coinage metals like Cu, Ag, Au of IB group.*Cl* is of VII a group and ‘Mn’ is of VII B, but chlorine is a non metal, where as manganese is a metal.

Think and discuss

- Why Mendeleeff had to leave certain blank spaces in his periodic table? What is your explanation for this?
- What is your understanding about Ea_2O_3, EsO_2?

Think and discuss

- All alkali metals are solids but hydrogen is a gas with diatomic molecules. Do you justify the inclusion of hydrogen in first group with alkali metals?

Modern Periodic Table

H.J. Moseley (1913) found that each element emits a characteristic pattern of X-rays when subjected to bombardment by high energy electrons. By analyzing the X-ray patterns, Moseley was able to calculate the number of positive charges in the atoms of respective elements. The number of positive charges (protons) in the atom of an element is called the atomic number of the element. With this analysis Moseley realised that the atomic number is more fundamental characteristic of an element than its atomic weight.

After knowing the atomic numbers of elements, it was recognized that a better way of arranging the elements in the periodic table is according to the increasing atomic number. This arrangement eliminated the problem of anomalous series. For example, though tellurium (Te) has more atomic weight than iodine (I), it has atomic number less by one unit compared to iodine. This atomic number concept forced the periodic law to be changed.

The periodic law is changed from atomic weight concept to atomic number concept and now it is called the *modern periodic law*.

We know that Mendeleeff's periodic law is stated as "The properties of elements are the periodic functions of their atomic weights". Now, let us try to understand modern periodic law.

The modern periodic law may stated as "the properties of the elements are periodic function of their atomic numbers."

Based on the modern periodic law, the modern periodic table which is given here (page 186) is proposed. It is the extension of the original Mendeleeff's periodic table known as short form of the table and this modern table is called the long form of the periodic table. It is given in fig (2). Atomic number of an element (Z) indicates not only the positive charges i.e., the protons in the nucleus of the atom of the element but also the number of electrons in the neutral atom of that element.

The physical and chemical properties of atoms of the elements depend not on the number of protons but on the number of electrons and their arrangements (electronic configurations) in atoms. Therefore, the modern periodic law may be stated as "The physical and chemical properties of elements are the periodic function of the electronic configurations of their atoms."

Positions of elements in the Modern Periodic Table

The modern periodic table has eighteen vertical columns known as *groups* and seven horizontal rows known as *periods.*

Let us see what decides the position of an element in modern periodic table.

We can explain the classification of the elements in the modern periodic table in terms of certain electron arrangements which are periodically repeated. The elements with similar outer shell (valence shell) electronic configurations in their atoms are in the same column called **group**. Elements listed in a group down to it are in the order of their increasing principal quantum numbers.

In the chapter 'Structure of atom' you have learnt that 's' sub-shell with one orbital contains a maximum of two electrons. Each 'p' sub-shell contains 3 orbitals and accommodates a maximum of six electrons. The'd' sub-shell contains 5 orbitals and accommodates a maximum of 10 electrons and 'f' sub-shell contains 7 orbitals with 14 electrons maximum. Depending upon to which sub-shell the differentiating electron. i.e., the last coming electron enters in the atom of the given element, the elements are classified as 's' 'p', 'd' and 'f' block elements.

For example, sodium (Na) gets its new coming electron (differentiating electron) into 3s level. Therefore 'Na' is an s-block element. Aluminium (Al) gets its differentiating electron into 'p' subshell and it is a p-block element. Scandium (Sc) gets its differentiating electron into 'd' subshell. Therefore it is a d-block element. Cerium (Ce) gets its new coming electron into 'f' subshell, hence,it is an f-block element.

Let us observe the electronic configurations of the following elements. The last coming electron is underlined.

$_{11}Na$ $1s^2\ 2s^2\ 2p^6\ \underline{3s^1}$

$_{13}Al$ $1s^2\ 2s^2\ 2p^6\ 3s^2\ \underline{3p^1}$

$_{21}Sc$ $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ \underline{3d^1}$

$_{58}Ce$ $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6\ 6s^2\ \underline{4f^1}$

The Modern Periodic Table of the Elements

H 1 1.008 Hydrogen — Symbol, Atomic Number, Atomic Wigight, Name

( ) = Estimates

Period	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	H 1 1.008 Hydrogen																	He 2 4.00 Helium
2	Li 3 6.94 Lithium	Be 4 9.01 Beryllium											B 5 10.81 Boron	C 6 12.01 Carbon	N 7 14.01 Nitrogen	O 8 16.00 Oxygen	F 9 19.00 Fluorine	Ne 10 20.18 Neon
3	Na 11 22.99 Sodium	Mg 12 24.31 Magnesium											Al 13 26.98 Aluminium	Si 14 28.09 Silicon	P 15 30.97 Phosphorus	S 16 32.07 Sulphur	Cl 17 35.45 Chlorine	Ar 18 39.95 Argon
4	K 19 39.10 Potassium	Ca 20 40.08 Calcium	Sc 21 44.96 Scandium	Ti 22 47.88 Titanium	V 23 50.94 Vanadium	Cr 24 52.00 Chromium	Mn 25 54.94 Manganese	Fe 26 55.85 Iron	Co 27 58.93 Cobalt	Ni 28 58.69 Nickel	Cu 29 63.55 Copper	Zn 30 65.39 Zinc	Ga 31 69.72 Gallium	Ge 32 72.61 Germanium	As 33 74.92 Arsenic	Se 34 78.96 Selenium	Br 35 79.90 Bromine	Kr 36 83.80 Krypton
5	Rb 37 85.47 Rubidium	Sr 38 87.62 Strontium	Y 39 88.91 Yitrium	Zr 40 91.22 Zirconium	Nb 41 92.91 Niobium	Mo 42 95.94 Molybdenum	Tc 43 (97.9) Technetium	Ru 44 (101.07) Ruthenium	Rh 45 (102.91) Rhodium	Pd 46 (106.42) Palladium	Ag 47 (107.87) Silver	Cd 48 (112.41) Cadmium	In 49 114.82 Indium	Sn 50 118.71 Tin	Sb 51 121.76 Antimony	Te 52 127.60 Tellurium	I 53 126.90 Tellurium	Xe 54 131.29 Xenon
6	Cs 55 132.91 Cesium	Ba 56 137.33 Barium	La 57 138.91 Lanthanum	Hf 72 178.49 Hafnium	Ta 73 180.95 Tantalum	W 74 183.85 Tungsten	Re 75 186.21 Rhenium	Os 76 190.2 Osmium	Ir 77 192.22 Iridium	Pt 78 195.08 Platinum	Au 79 196.97 Gold	Hg 80 200.59 Mercury	Tl 81 204.38 Thallium	Pb 82 207.2 Lead	Bi 83 208.98 Bismuth	Po 84 (209) Polonium	At 85 (210) Astatine	Rn 86 (222) Radon
7	Fr 87 223.02 Francium	Ra 88 226.02 Radium	Ac 89 227.03 Actinium	Rf 104 (261) Rutherfordium	Db 105 (262) Dubnium	Sg 106 (263) Seaborgium	Bh 107 (262) Bohrium	Hs 108 (265) Hassium	Mt 109 (266) Meitnerium	Ds 110 (269) Darmstadium	Rg 111 (272) Roentgenium	Cn 112 (277) Copernicium		Fl 114 (287) Flerovium		Lv 116 (289) Livermorium		Unnamed Discovery 118 Nov.1999
	ALKALI METALS	ALKALI EARTH METALS															HALOGENS	NOBLE GASES

LANTHANIDES	Ce 58 140.12 Cerium	Pr 59 140.91 Praseodymium	Nd 60 144.24 Neodymium	Pm 61 (145) Promethium	Sm 62 150.36 Samarium	Eu 63 152.97 Europium	Gd 64 157.25 Gadolinium	Tb 65 158.93 Terbium	Dy 66 162.50 Dysprosium	Ho 67 164.93 Holmium	Er 68 167.26 Erbium	Tm 69 168.93 Thulium	Yb 70 173.04 Ytterbium	Lu 71 174.97 Lutetium
ACTINIDES	Th 90 232.04 Thorium	Pa 91 231.04 Protacinium	U 92 238.03 Uranium	Np 93 237.05 Neptunium	Pu 94 (240) Plutonium	Am 95 243.06 Americium	Cm 96 (247) Curium	Bk 97 (248) Berkelium	Cf 98 (251) Californium	Es 99 252.08 Einsteinium	Fm 100 257.10 Fermium	Md 101 (257) Mendelevium	No 102 259.10 Nobelium	Lr 103 262.11 Lawrencium

Z	Elements	n	1	2		3			4				5				6
		l	0	0	1	0	1	2	0	1	2	3	0	1	2	3	0
		Sub Shell	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s
11	Na		2	2	6	$\underline{1}$											
13	Al		2	2	6	2	$\underline{1}$										
21	Sc		2	2	6	2	6	$\underline{1}$	2								
58	Ce		2	2	6	2	6	10	2	6	10	$\underline{1}$	2	6	1		2

Groups

The vertical columns in the periodic table are known as groups. There are eighteen groups in long form of periodic table. They are represented by using Roman numeral I through VIII with letters A and B in traditional notation.

According to latest recommendation of the IUPAC, these groups are represented by Arabic numerals 1 through 18 with no A and B designations. We use the latest system with the traditional heading following in parenthesis.

Eg: Group 2 (II A); Group 16 (VI A)

Group of elements is also called *element family* or *chemical family*.

For example Group 1 (IA) has from Li to Fr with outer shell electronic configuration ns^1 and is called *Alkali metal* family.

Activity 2

Some main group elements of s-block and p-block have family names as given in the following table.

Observe the long form of the periodic table and complete the table with proper information.

Group No.	Name of the element family	Elements From	Elements To	Valence shell configuration	Valence electrons	Valency
1 (IA)	Alkali metal family	Li	Fr	ns^1	1	1
2 (IIA)	Alkali earth metal family					
13 (IIIA)	Boron family					
14 (IVA)	Carbon family					
15 (VA)	Nitrogen family					
16 (VIA)	Oxygen family or (Chalcogen family)					
17 (VIIA)	Halogen family					
18 (VIIIA)	Noble gas family					

Periods

The horizontal rows in the periodic table are called periods. There are seven periods in the modern periodic table. These periods are represented by Arabic numerals 1 through 7.

1. The number of main shells present in the atom of particular element decides to which period it belongs. For example, hydrogen (H) and helium (He) atoms contain only one main shell (K). Therefore they belongs to period-1. Similarly, the elements Li, Be, B, C, N, O, F and Ne contain two main shells (K and L) in their atoms. Therefore they belong to period-2.

Do you know?

- Do you know how are the names of certain families of periodic table derived?
  Alkali metal family: aliquili = plantashes, Na, K etc.... were obtained from plant ash, group IA elements are called alkali metals family.
  Chalcogen family: chalcogenous = ore product, as the elements in group 16(VIA) form ores with metals. They are called as chalcogenous family.
  Halogen family: halos = sea salt, genus = produced. As most of the elemetns in group 17(VIIA) are obtained from nature as sea salt. They are called as halogen family.
  Noble gases: as the elements of group 18(VIIIA) are chemically least active. They are called as noble gases. There outer shell electronic configurations are basis for octet rule.

2. The number of elements in period depend on how electrons are filled into various shells. Each period starts with a new main shell 's' subshell and ends when the main shell is filled with respect to the 's' and 'p' subshells (except the first period).
   The first period starts with K-shell. The first main shell (K) contains only one sub-shell, the (1s). For this subshell only two types of electronic configurations are possible and they are $1s^1$ (H) and $1s^2$ (He). Therefore, the first period contains only two elements.
3. Second period starts with the 2nd main shell (L). L-shell has two sub-shells, namely, 2s and 2p. Eight types of configurations are possible in this shell (L) like $2s^1$ and $2s^2$ and $2p^1$ to $2p^6$. Hence the second period contains 8 elements Li, Be, B, C, N O, F and Ne in the order given. Thus, the 2nd period consists two s-block elements (Li, Be) and six p-block elements (B to Ne).

4. Third period starts with third main shell (M). This shell (M) has 3 sub-shells, namely, 3s, 3p and 3d, but while electrons are being filled into the shell '3d' gets electrons only after '4s' is filled. Therefore, the 3rd period contains again 8 elements, which includes two s-block elements (Na, Mg) and six p-block elements (Al to Ar).
5. Fourth main shell (N). This shell (N) has four sub-shells namely 4s, 4p, 4d and 4f, but while electrons are being filled into the shell , electrons enter the atoms in the order 4s, 3d and 4p. Due to this, the fourth period contains 18 elements which includes two s-block (K, Ca), 10 elements from d block (Sc to Zn) and six elements from p-block ($_{31}$Ga to $_{36}$ Kr). There are altogether eighteen elements in the fourth period.

On the same lines, we can explain why there are 18 elements in the fifth period ($_{37}$Rb to $_{54}$Xe).

There are thirty two elements in the Sixth period from $_{55}$Cs to $_{86}$ Rn which includes 2 elements from s-block (6s) and 14 elements from f-block (4f). 10 elements from d-block (5d) and 6 elements from p-block (6p).

'4f' elements are called *Lanthanoids* or *lanthanides*. Elements from $_{58}$Ce to $_{71}$Lu possess almost the same properties as $_{57}$ La. So, the name lanthanoids is the most appropriate one for these elements.

7th period is incomplete and contains 2 elements from s-block (7s) and 14 elements from f-block (5f), 10 elements from d-block (6d) and some elements from p-block (7p). The 5f elements are called *Actinoids* or as *Actinides*. They are from $_{90}$Th to $_{103}$Lr .

The f-block elements known as lanthanoids and actinoids are shown separately at the bottom of the periodic table.

? Do you know?

'*Ide'* means 'heir' and it is used generally for a change like C*l* to C*l*$^-$. 'C*l*' is chlorine atom and Cl$^-$ is chloride ion. '*Oid'* means 'the same'.

Some scientists suggest lanthanoids as $_{57}$La to $_{70}$Yb, some suggest them as $_{58}$Ce to $_{71}$Lu and some take $_{57}$La to $_{71}$Lu (15 elements). There is another argument that even $_{21}$Sc and $_{39}$Y should be included in lanthanoids. All these suggestions have substance because $_{21}$Sc, $_{39}$Y and $_{57}$La to $_{71}$Lu all have the similar outer shells configurations.

Also in the case of actinoids. There are different arguments like actinoids are from $_{90}$Th to $_{103}$Lr or $_{89}$Ac to $_{102}$No or $_{89}$Ac to $_{103}$Lr.

Think and discuss

- Why lanthanoids and actinoids placed separately at the bottom of the periodic table?
- If they are inserted within the table imagine how the table would be?

Metals and Non metals

You have learnt about the properties of metals in the chapter Metals and Non Metals in class VIII. Let us study the metallic properties elements in periodic table.

The elements with three or less electrons in the outer shell are considered to be metals and those with five or more electrons in the outer shell are considered to be non metals. We may find some exceptions to this. 'd' block elements (3^{rd} group to 12^{th} group) are metals and they are also known as transition metals and the metallic character of d-block elements decreases gradually from left to right in periodic table. Lanthanoids and actinoids actually belong to 3^{rd} group (III B) which is within the transition elements: hence they are called the inner transition elements.

Metalloids or semi-metals are elements which have properties that are intermediate between the properties of metals and non metals. They possess properties like metals but brittle like non metals. They are generally semi conductors. Eg: B, Si, Ge.

All elements in s-block are metals, whereas in p-block (except 18^{th} group) there are metals, non metals and metalloids. In periodic table you will notice a staircase like demarcation. The elements to the left of this demarcation are metals and to the right are non-metals. The elements on staircase (or) very near to it like B, Si, As, Ge etc., are metalloids.

Periodic properties of the elements in the modern table

The modern periodic table is organized on the basis of the electronic configuration of the atoms of elements. Physical and chemical properties of elements are related to their electronic configurations particularly the outer shell configurations. The atoms of the elements in a group possess similar electronic configurations. Therefore, we expect all the elements in a group should have similar chemical properties and there should be a regular gradation in their physical properties from top to bottom.

Similarly, across the table, i.e., from left to right in any period elements get an increase in the atomic number by one unit between any two successive elements. Therefore, the electronic configuration of valence shell of any two elements in a given period is not same. Due to this reason elements along a period possess different chemical properties with regular gradation in their physical properties from left to right. To understand this we will take some properties of elements and discuss how they vary in groups and in periods.

Properties of elements and their trends in Groups and in Periods

1. Valence: Valence (or) valency of an element was defined as the combining power of an element with respect to hydrogen, oxygen or indirectly any other element through hydrogen and oxygen.

Valence of an element with respect to hydrogen is the number of hydrogen atoms with which one atom of that element chemically combines. Valence of an element with respect to oxygen is twice the number of oxygen atoms with which one atom of that element combines.

For example one atom of 'Na' chemically combines with one atom of 'H' to give NaH. Therefore, the valence of Na is 1. One atom of 'Ca' combines with one atom of 'O' to give CaO. So the valency of Ca is 2.

In general, the valence of an element with respect to hydrogen is its traditional group number. If the element is in the group V or above, its valence is *8– group number*. For example, chlorine valence is 8-7 = 1.

In general, each period starts with valency 1 for 1^{st} group elements, increases upto 4 with respect to the group number and then decreases from 4 to 3 to 2 to 1 to zero in the following groups (this is applicable only for main group elements i.e., 's' and 'p' block elements.

Now a days the valence of an elment is generally taken as the number of valence shell (outer most shell) electrons in its atom. Oxidation number concept almost is the latest subsititute to the valence concept in the modern literatura.

Activity 3

- Find out the valencies of first 20 elements.
- How does the valency vary in a period on going from left to right?
- How does the valency vary on going down a group?

Atomic radius

Atomic radius of an element may be difined as the distance from the centre of the nucleus of the atom to its outermost shell.

Atomic radius of an element is not possible to measure in its isolated state. This is because it is not possible to determine the location of the electron that surrounds the nucleus. However, we can measure the distance between the nuclei of adjacent atoms in a solid. From this we can estimate the size of the atom by assigning half of this distance to the radius of each atom. This method is best suited to elements such as the metals that exist in the solid state. More than 75 percent of the elements are metals and atomic radii of metals are called *metallic radii*. Another way of estimating the size of an atom is to measure the distance between the two atoms in covalent molecules. The size of a chlorine atom is estimated by measuring the length of the covalent bond between two chlorine atoms in a Cl_2 molecule. Half of this distance is taken as *atomic radius* which is called as the *covalent radius* of chlorine atom.

Atomic radius is measured in 'pm' (pico meter) units.

1 pm = 10^{-12}m

Variation of atomic radii in group

Atomic radii increase from top to bottom in a group (column) of the periodic table. As we go down in a group, the atomic number of the element increases. Therefore to accommodate more number of electrons, more shells are required. As a result the distance between the nucleus and the outer shell of the atom increases as we go down the group in spite of increase in nuclear change.

Group	Element (atomic radius in pm)
Group1:	Li (152), Na (186), K (231), Rb (244) and Cs (262)
Group 17:	F (64), C*l* (99), Br (114), I (133) and At (140)

Variation of atomic radii in period

Atomic radii of elements decrease across a period from left to right. As we go to right, electrons enter into the same main shell or even inner shell in case of 'd' block and 'f' block elements. Therefore, there should be no change in distance between nucleus and outer shell but nuclear charge increases because of the increase in the atomic number of elements in period. Hence, the nuclear attraction on the outer shell electrons increases. As a result the size of the atom decreases.

Period	Element (atomic radius in pm)
2nd period	Li (152), Be (111), B (88), C (77), N (74), O (66), F (64)
3rd period	Na (186), Mg (160), Al (143), Si (117), P(110), S(104), C*l*(99)

- Do the atom of an element and its ion have same size?

  Let us consider the following situation.

Assume that sodium (Na) atom has lost an electron and formed a cation of sodium (Na^+).

Which one between Na and Na^+ would have more size? Why?

Atomic number of sodium (Na) is 11. Therefore sodium (Na) atom contains 11 protons and 11 electrons with outer electron as $3s^1$. On the other hand Na^+ ion has 11 protons but only 10 electrons. The 3s shell of Na^+ level has no electron in it. Hence its outer shell configuration is $2s^2\ 2p^6$. As proton number is more than electrons in it, the nucleus of Na^+ ion attracts outer shell electrons with strong nuclear force. As a result the Na^+ ion shrinks in size. Therefore, the size of Na^+ ion is less than 'Na' atom. In general the positive ion (cation) of an element has less size than its neutral atom.

Consider another example: Assume that chlorine (C*l*) atom has gained an electron to form anion of chlorine (Cl^-) i.e. chloride ion.

- Which one, between C*l* and Cl^- would have more size? Why?

Electronic configuration of chlorine (C*l*) atom is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ and the electronic configuration of chloride (Cl^-) ion is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. Both chlorine and chloride ion have 17 protons each but there are 17 electrons in chlorine atom, where as 18 electrons in chloride ion. Therefore, the nuclear attraction is less in Cl^- ion when compared with chlorine atom. Therefore the size of the chlorine (C*l*) atom is less size than Cl^- ion. In general negative ion (anion) of an element has bigger size than its neutral atom.

- Which one in each of the following pairs is larger in size?

  (a) Na, Al (b) Na, Mg^{+2} (c) S^{2-}, Cl^- (d) Fe^{2+}, Fe^{3+} (e) C^{4-}, F^-

Ionization Energy

The energy required to remove an electron from the outer most orbit or shell of a neutral gaseous atom is called ionization energy. The energy required to remove the first electron from the outer most orbit or shell of a neutral gaseous atom of the element is called its first ionization energy. The energy required to remove the an electron from uni- positive ion of the element is called the 2nd ionization energy of that element and so on.

$M_{(g)} + IE_1 \rightarrow M^+_{(g)} + e^-$ (IE_1= first ionization energy)

$M^+_{(g)} + IE_2 \rightarrow M^{+2}_{(g)} + e^-$ (IE_2= second ionization energy)

Think and discuss

- Second ionization energy of an element is higher than its first ionization energy. why?

Ionization energy of an element depends on its

1. Nuclear charge: more the nuclear charge more is the ionization energy.**eg:**Between $_{11}$Na and $_{17}$*Cl*, Chlorine atom has more ionization energy.

2. Screening effect or sheilding effect: more the shells with electrons between the nucleus and the valence shell, they act as screens and decrease nuclear attraction over valence electron. This is called the *screening effect.* More the screening effect, less is the ionization energy. Between $_3$Li and $_{55}$Cs, the element $_{55}$Cs with more inner shells has less ionization energy.

3. Penetration power of the orbitals: orbitals belonging to the same main shell have diffrent piercing power towards the nucleus, for examle 4s>4p>4d>4f> in the penetration. There fore, it is easier to remove 4f electron than 4s. Between $_4$Be $1s^2\ 2s^2$ and B $1s^2\ 2s^2\ 2p^1$, the element B has less ionization energy due to less penetration power of '2p' compared to '2s'

4. Stable configuration: it is easier to remove one electron from $_8$O ($1s^2 2s^2 2p^4$) than $_7$N ($1s^2 2s^2 2p^3$). This is because, $_7$N has stable half filled configuration.

5. Atomic radius: more the atomic radius, less is the ionization energy. Therefore, ionization energy of 'F' is greater than that of 'I' and the ionization energy of 'Na' is more than that of 'Cs'.

Ionization energy decreases as we go down in a group and generally increases from left to right in a period.

Ionization energy is expressed in kJ mol^{-1}

Ionization energy is also called the ionization potential but when we use the term the ionization potential, it is better to write the unit eV atom^{-1}.

Electron affinity

Atoms of some elements gain electrons while forming ionic compounds. An atom is able to gain an electron only when the electron outside the atom is attracted by its nucleus. Attraction involves the liberation of energy.

The electron affinity of an element is defined as the energy liberated when an electron is added to its neutral gaseous atom. Electron affinity of an element is also called electron gain enthalpy of that element.

$M_{(g)} + e^- \rightarrow M^-_{(g)} + EA$ (EA = Electron affinity)

The energy liberated when an electron is added to a uni-negative ion of the element is called the 2nd electron affinity of that element. However, practically no element shows liberation of energy when the 2nd electron is added to its uni-negative ion. It does not mean that di-negative or tri-negative ions do not form. They do form, but for adding 2nd electron, energy in another way like bond formation must be given.

Electron affinity values of halogens are (in kJ mol^{-1}); F(-328); Cl(-349); Br (-325); I(-295) kJ mol^{-1} . Similarly for group 16 elements, the electron gain enthalpies are O(-141); S(-200); Ge(-195) and Te(-190) kJ mol^{-1}.

Electron gain enthalpy values decrease as we go down in a group, but increase along a period from left to right. Metals have very low electron gain enthalpy values and alkaline earth metals have even positive values. Note that the negative sign for energy value in table indicates that energy is liberated or lost, and the positive sign tells that the energy is gained or absorbed. All the factors which influence the ionization energy would also influence the electron gain enthalpy.

Think and discuss

- The calculated electron gain enthalpy values for alkaline earth metals and noble gases are positive. How can you explain this?
- The second period element for example 'F' has less electron gain enthalpy than the third period element of the same group for example '*Cl*'. Why?

Electronegativity

The ionization energy and the electron gain enthalpy are properties of isolated atoms of elements. There has been a need to have a comparative scale relating the abilities of elements to attract electrons when their atoms are combined. For this purpose, the concept of electronegativity is introduced.

The *electronegativity* of an element is defined as the relative tendency of its atom to attract electrons towards it self when it is bonded to the atom of another element.

All the factors that influence the ionization energy and the electron affinity of elements influence the electronegativity values of those elements. Because of this, Milliken proposed that the electronegativity of an element is the average value of its ionization energy and electron affinity.

$$\text{Electronegativity} = \frac{\text{ionization energy} + \text{electron affinity}}{2}$$

Pauling assigned the electronegativity values for elements on the basis of bond energies. He assumed that the electronegativity of hydrogen is 2.20 and calculated the values of other elements with respect to hydrogen. Observe the values in the following example

Period	Element (electronegativity with respect hydrogen)
Halogens:	F(4.0), C*l*(3.0), Br(2.8), I(2.5)
2^{nd} period:	Li(1.0), Be(1.47), B(2.0), C(2.5), N(3.0), O(3.5), F(4.0), Ne(-)

Electronegativity values of elements decrease as we go down in a group and increase along a period from left to right. The most electronegative element is 'F' and the least electronegative stable element is 'Cs'.

Metallic and Non-Metallic Properties

Metals generally show less electronegative character. In compounds, they generally show a tendency to remain as positive ions. This property is often termed as electropositive character. Metals are electropositive elements.

Non metals are generally more electronegative due to their smaller atomic radii.

Let us examine the elements of 3^{rd} period.

3^{rd} period:	Na	Mg	Al	Si	P	S	C*l*

We know that Na and Mg are metals, Al and Si are semi metals (metalloids), P, S and C*l* are non metals. So we find metals on left side and non metals on right side of the periodic table. This means metallic character decreases while non metallic character increases as we move along a period (from left to right).

Let us take group 14 (IVA) elements.

IVA group: C Si Ge Sn Pb

Here also we know that carbon is nonmetal. Si and Ge are metalloids. Sn and Pb are metals.

So we find nonmetals particularly at the right hand side top and metals at the left and right hand side bottom of the periodic table. This means metallic character increases while non metallic character decreases in a group as we move from top to bottom.

Key words

Triad, Octave, Periodic Law, Periodic table, period, group, Lanthanides, Actinides, Element family, Metalloids, Periodicity, Atomic radius, Ionization energy, Electron affinity, Electronegativity, Electropositivity

What we have learnt

- Elements are classified on the basis of similarities in their Properties.
- Dobereiner grouped the elements into Triads and Newlands gave the law of Octaves.
- Mendeleeff's Periodic law: The physical and chemical Properties of the elements are the periodic functions of their Atomic Masses.
- Moseley's Periodic law : The physical and chemical properties of the elements are the periodic functions of their Atomic numbers.
- Modern Periodic Law: The Physical and chemical Properties of the elements are the periodic functions of their Electronic Configurations.
- Anomalies in arrangement of elements based on increasing atomic mass could be removed when the elements were arranged in order of increasing atomic number, a fundamental property of the element discovered by Moseley.
- Elements in the Modern Periodic table are arranged in 18 groups and 7 periods.
- Elements are classified into s, p, d, f blocks, depending upon to which sub shell the differentiating electron enters in the atom of the given element.
- All the d- block elements (except Zn group) are known as transition elements and all the f-block elements (both Lanthanides, Actinides) are known as inner transition elements.
- Periodic properties of elements and their trends in groups and in periods

Periodic property	Trend in	
	groups	periods
	From top to bottom	From left to right
Valency		
Atomic radius	Increasing	Decreasing
Ionisation energy	Decreasing	Increasing
Electron affinity	Decreasing	Increasing
Electronegativity	Decreasing	Increasing
Electropositivity	Increasing	Decreasing
Metallic nature	Increasing	Decreasing
Non-Metallic nature	Decreasing	Increasing

Improve your learning

1. Newlands proposed the law of octaves. Mendeleeff suggested eight groups for elements in his table. How do you explain these observations in terms of modern periodic classification?(AS1)
2. What are the limitations of Mendeleeff's periodic table? How could the modern periodic table overcome the limitations of Mendeleeff's table? (AS1)
3. Define the modern periodic Law. Discuss the construction of the long form of the periodic table. (AS1)
4. Explain how the elements are classified into s, p, d and f- block elements in the periodic table and give the advantage of this kind of classification. (AS1)
5. Given below is the electronic configuration of elements A, B, C, D. (AS1)

   A. $1s^2\ 2s^2$
   B. $1s^2\ 2s^2\ 2p^6\ 3s^2$
   C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$
   D. $1s^2\ 2s^2\ 2p^6$

   1. Which are the elements coming with in the same period
   2. Which are the ones coming with in the same group?
   3. Which are the noble gas elements?
   4. To which group and period does the elements 'C 'belong
6. Write down the characteristics of the elements having atomic number 17. (AS1)

   Electronic configuration ____________________
   Period number ____________________
   Group number ____________________
   Element family ____________________
   No. of valence electrons ____________________
   Valency ____________________
   Metal or non-metal ____________________
7. **a.** State the number of valence electrons, the group number and the period number of each element given in the following table: (AS1)

Element	Valence electrons	Group number	Period number
Sulphur			
Oxygen			
Magnesium			
Hydrogen			
Fluorine			
Aluminum			

b. State whether the following elements belong to a Group **(G)**, Period **(P)** or Neither Group nor Period **(N)**. (AS1)

Elements	G/P/N
Li,C,O	
Mg, Ca, Ba	
Br, Cl, F	
C,S, Br	
Al, Si, C*l*	
Li, Na, k	
C,N,O	
K, Ca, Br.	

8. Elements in a group generally possess similar properties, but elements along a period have different properties. How do you explain this statement? (AS1)
9. s - block and p - block elements except 18th group elements are sometimes called as 'Representative elements' based on their abundant availability in the nature. Is it justified? Why? (AS1)
10. Complete the following table using the periodic table. (AS1)

Period number	Filling up orbital's (sub shells)	Maximum number of electrons, filled in all the sub shells	Total no. of elements in the period
1			
2			
3			
4	4s, 3d, 4p	18	18
5			
6			
7	7s, 5f, 6d, 7p	32	incomplete

11. Complete the following table using the periodic table. (AS1)

Period number	Total no. of elements	Elements		Total no. of elements in			
		From	To	s-block	p-block	d-block	f-block
1							
2							
3							
4							
5							
6							
7							

12. The electronic configuration of the elements X, Y and Z are given below?

    a) X = 2 b) Y = 2, 6 c) Z = 2, 8, 2

    i) Which element belongs to second period? ii) Which element belongs to second group?

    iii) Which element belongs to 18th group?

13. Identify the element that has the larger atomic radius in each pair of the following and mark it with a symbol (✓). (AS1)

    (i) Mg or Ca (ii) Li or Cs (iii) N or P (iv) B or Al

14. Identify the element that has the lower Ionization energy in each pair of the following and mark it with a symbol (✓). (AS1)

    (i) Mg or Na (ii) Li or O (iii) Br or F (iv) K or Br

15. In period 2, element **X** is to the right of element Y. Then, find which of the elements have:

    (i) Low nuclear charge (ii) Low atomic size (iii) High ionization energy

    (iv) High electronegativity (v) More metallic character (AS1)

16. How does metallic character change when we move

    i. Down a group ii. Across a period?

17. Why was the basis of classification of elements changed from the atomic mass to the atomic number? (AS1)

18. What is a periodic property? How do the following properties change in a group and period? Explain. (AS1)

    (a) Atomic radius (b) Ionization energy (c) Electron affinity (d) Electronegativity.

    (b) Explain the ionization energy order in the following sets of elements:

    a) Na, Al, C*l* b) Li, Be, B c) C, N, O d) F, Ne, Na e) Be, Mg, Ca. (AS1)

19. Name two elements that you would expect to have chemical properties similar to Mg. What is the basis for your choice? (AS2)

20. On the basis of atomic numbers predict to which block the elements with atomic number 9, 37, 46 and 64 belongs to? (AS2)

21. Using the periodic table, predict the formula of compound formed between and element X of group 13 and another element Y of group 16. (AS2)

22. An element **X** belongs to 3rd period and group 2 of the periodic table. State
    (a) The no. of valence electrons (b) The valency (c) Whether it is metal or a nonmetal. (AS2)
23. An element has atomic number 19. Where would you expect this element in the periodic table and why? (AS2)
24. Aluminium does not react with water at room temperature but reacts with both dil. HC*l* and NaOH solutions. Verify these statements experimentally. Write your observations with chemical equations. From these observations, can we conclude that A*l* is a metalloid? (AS3)
25. Collect the information about reactivity of VIII A group elements (noble gases) from internet or from your school library and prepare a report on their special character when compared to other elements of periodic table. (AS4)
26. Collect information regarding metallic character of elements of IA group and prepare report to support the idea of metallic character increases in a group as we move from top to bottom. (AS4)
27. How do you appreciate the role of electronic configuration of the atoms of elements in periodic classification? (AS6)
28. Without knowing the electronic configurations of the atoms of elements Mendeleev still could arrange the elements nearly close to the arrangements in the Modern periodic table. How can you appreciate this? (AS 6)
29. Comment on the position of hydrogen in periodic table. (AS7)
30. How the positions of elements in the periodic table help you to predict its chemical properties? Explain with an example. (AS7)

Fill in the blanks

1. Lithium, ______________ and potassium constitute a Dobereiner's triad.
2. _______ was the basis of the classifications proposed by Dobereiner, Newlands and Mendeleeff.
3. Noble gases belongs to ________________ group of periodic table.
4. The incomplete period of the periodic table is ______________ .
5. The element at the bottom of a group would be expected to show __________ metallic character than the element at the top.

Multiple choice questions

1. Number of elements present in period – 2 of the long form of periodic table [ ]
   a) 2 b) 8 c) 18 d) 32
2. Nitrogen (Z = 7) is the element of group V of the periodic table. Which of the following is the atomic number of the next element in the group? [ ]
   a) 9 b) 14 c) 15 d) 17
3. Electron configuration of an atom is 2, 8, 7 to which of the following elements would it be chemically similar? [ ]
   a) nitrogen(Z=7) b) fluorine(Z=9) c) phosphorous(Z=15) d) argon(Z=18)
4. Which of the following is the most active metal? [ ]
   a) lithium b) sodium c) potassium d) rubidium