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# PERIODIC CLASSIFICATION OF ELEMENTS

In the last lesson, you have studied about the structure of atoms and their electronic configurations. You have also learnt that the elements with similar electronic configurations show similar chemical properties. By the middle of the nineteenth century quite a large number of elements (nearly 60) were known. In order to study these elements systematically, it was considered necessary to classify them. In this lesson, you will undertake the journey through the development of classification of elements from ancient to modern. You will also study how some properties of elements vary in the modern periodic table.

## OBJECTIVES

After studying this lesson you will be able to:

- *describe briefly the development of classification of elements;*
- *state main features of Mendeleev's periodic table;*
- *explain the defects of Mendeleev's periodic table;*
- *state modern periodic law;*
- *describe the features of the long form of periodic table;*
- *explain modern periodic classification and*
- *describe the trends in variation of atomic size and metallic character in the periodic table.*

## 6.1 CLASSIFICATION OF ELEMENTS

### 6.1.1 Need for Classification of Elements

You must have visited a chemist's shop. Several hundred medicines are stored in it. In spite of this, when you ask for a particular medicine, the chemist is able to locate it easily. How is it possible? It is because the medicines have been *classified* into various categories and sub categories and arranged accordingly. This makes their location an easy task.

Before the beginning of the eighteenth century, only a few elements were known, so it was quite easy to study and remember the properties of those elements and their compounds individually. However, by the middle of the nineteenth century, more the than sixty elements had been discovered. The number of compounds formed by them was also enormous. With the increasing number of elements, it was becoming more and more difficult to study their properties individually. Therefore, the need for their classification was felt. This led to the classifications of various elements into groups which helped in the systematic study of elements.

### 6.1.2 Development of Classification

Scientists after many attempts were successful in arranging various elements into groups. They realised that even though every element is different from others, yet there are a few similarities among some elements. Accordingly, similar elements were arranged into groups which led to classification. Various types of classification were proposed by different scientists. The first classification of elements was into 2 groups- **metals** and **non-metals**. This classification served only limited purpose mainly because some elements like germanium and antimony showed the properties of both – metals and non-metals. They could not be placed in any of the two classes.

Scientists were in search of such characteristics of an element which would never change. After the work of William Prout in 1815, it was found that the atomic mass of an element remains constant, so it could form the basis for a satisfactory classification. Now, you will learn about the *four* major attempts made for classification of elements. They are as follows :

1. Dobereiner's Triads
2. Newlands' Law of Octaves
3. Mendeleev's Periodic Law & Periodic Tables
4. Modern Periodic Table

### 6.1.3 Dobereiner's Triads

In 1829, J.W. Dobereiner, a German chemist made groups of three elements each and called them **triads** (Table 6.1). All three elements of a triad were similar in their physical and chemical properties. He proposed a law known as **Dobereiner's law of triads**. According to this law, *when elements are arranged in order of increasing atomic mass, the atomic mass of the middle element was nearly equal to the arithmetic mean of the other two and its properties were intermediate between those of the other two.*

J.W. Dobereiner
(1780-1849)

**Table 6.1: Dobereiner's triads of elements**

| S. No. | Element | Atomic Mass | Mean of I and III |
|---|---|---|---|
| 1. | I. Lithium<br>II. Sodium<br>III. Potassium | 7<br>23<br>39 | $\frac{7+39}{2}=23$ |
| 2. | I. Calcium<br>II. Strontium<br>III. Barium | 40<br>88<br>137 | $\frac{40+137}{2}=88.5$ |
| 3. | I. Chlorine<br>II. Bromine<br>III. Iodine | 35.5<br>80<br>127 | $\frac{35.5+127}{2}=81.25$ |

This classification did not receive wide acceptance since only a few elements could be arranged into triads.

### 6.1.4 Newlands' Law of Octaves

In 1864, an English chemist John Alexander Newlands arranged the elements in the increasing order of their atomic masses (then called *atomic weight*). He observed that *every eighth element had properties similar to the first element*. Newlands called it the **Law of Octaves**. It was due to its similarity with musical notes where every eighth note is the repetition of the first one as shown below :

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|
| सा | रे | गा | मा | पा | धा | नी | सा |

The arrangement of elements given by Newlands is given in Table 6.2.

Starting from *lithium* (Li), the eighth element is *sodium* (Na) and its properties are similar to those of the lithium. Similarly, *beryllium* (Be), *magnesium* (Mg) and *calcium* (Ca) show similar properties. *Fluorine* (F) and *chlorine* (Cl) are also similar chemically.

**Table 6.2 : Arrangement of some elements with their atomic masses according to the Law of Octaves.**

| | | | | | | |
|---|---|---|---|---|---|---|
| Li (7) | Be (9) | B (11) | C (12) | N (14) | O (16) | F (19) |
| Na (23) | Mg (24) | Al (27) | Si (28) | P (31) | S (32) | Cl (35.5) |
| K (39) | Ca (40) | | | | | |

The **merits of Newlands'** Law of Octaves classification are:

(i) Atomic mass was made the basis of classification.

(ii) Periodicity of properties (the repetition of properties after a certain interval) was recognised for the first time.

The demerits of Newlands' law of Octaves are:

(i) It was not applicable to elements of atomic masses higher than 40 u. Hence, all the 60 elements known at that time, could not be classified according to this criterion.

(ii) With the discovery of noble gases, it was found that it was the *ninth* element which had the properties similar to the first one and *not the eighth* element. This resulted in the rejection of the very idea of octaves.

The basic idea of Newlands for using the atomic mass as the fundamental property for classification of elements was pursued further by two scientists Lother Meyer and D. Mendeleev. Their main achievement was that they both included almost all the known elements in their work. We shall, however, discuss the classification proposed by Mendeleev which was accepted more widely and is the basis of the modern classification.

### 6.1.5 Mendeleev's Periodic Law and Periodic Table

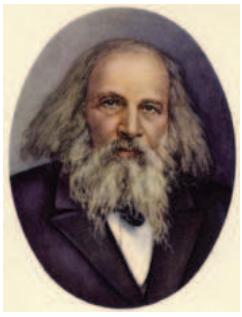
D'mitri Mendeleev (also spelled as Mendeleef or Mandeleyev ) , a Russian chemist studied the properties of all the 63 elements known at that time and their compounds. On arranging the elements in the increasing order of atomic masses, he observed that the elements with similar properties occur periodically. In 1869, he stated this observation in the form of the following statement which is known as the **Mendeleev's Periodic Law**.

*The chemical and physical properties of elements are a periodic function of their atomic masses.*

A *periodic function* is the one which repeats itself after a certain interval. Mendeleev arranged the elements in the form of a table which is known as the **Mendeleev's Periodic Table.**

#### Mendeleev's Periodic Table

Mendeleev arranged the elements in the increasing order of their atomic masses in horizontal rows till he came across an element whose properties were similar to those of the first element. Then he placed this element below the first element and thus started the second row of elements.



D. Mendeleev
(1834-1907)

The success of Mendeleev's classification was due to the fact that he laid more emphasis on the properties of elements rather than on atomic masses. Occasionally, he could not find an element that would fit in a particular position. He left such positions vacant for the elements that were yet to be discovered. He even predicted the properties of such elements and of some of their compounds fairly accurately. In some cases, he even reversed the order of some elements, if it better

matched their properties. Proceeding in this manner, he could arrange all the known elements in his periodic table.

When more elements were discovered, this periodic table was modified and updated to include them. One more group (zero group) had to be added when noble gases were discovered.

**Table 6.3: Mendeleev's updated periodic table**

| Groups | I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|
| Oxides Hydrides | $R_2O$ $RH$ | $RO$ $RH_2$ | $R_2O_3$ $RH_3$ | $RO_2$ $RH_4$ | $R_2O_5$ $RH_3$ | $RO_3$ $RH_2$ | $R_2O_7$ $RH$ | $RO_4$ |
| Periods ↓ | A B | A B | A B | A B | A B | A B | A B | Transition series |
| 1 | H 1.008 | | | | | | | |
| 2 | Li 6.939 | Be 9.012 | B 10.81 | C 12.011 | N 14.007 | O 15.999 | F 18.998 | |
| 3 | Na 22.99 | Mg 24.31 | Al 29.98 | Si 28.09 | P 30.974 | S 32.06 | Cl 35.453 | |
| 4 First series: Second series: | K 39.102 Cu 63.54 | Ca 40.08 Zn 65.37 | Sc 44.96 Ga 69.72 | Ti 47.90 Ge 72.59 | V 50.94 As 74.92 | Cr 50.20 Se 78.96 | Mn 54.94 Br 79.909 | Fe 55.85 Co 58.93 Ni 58.71 |
| 5 First series: Second series: | Rb 85.47 Ag 107.87 | Sr 87.62 Cd 112.40 | Y 88.91 In 114.82 | Zr 91.22 Sn 118.69 | Nb 92.91 Sb 121.75 | Mo 95.94 Te 127.60 | Tc 99 I 126.90 | Ru 101.07 Rh 102.91 Pd 106.4 |
| 6 First series: Second series: | Cs 132.90 Au 196.97 | Ba 137.34 Hg 200.59 | La 138.91 Tl 204.37 | Hf 178.49 Pb 207.19 | Ta 180.95 Bi 208.98 | W 183.85 | | Os 190.2 Ir 192.2 Pt 195.09 |

## Main Features of Mendeleev's Periodic Table

The following are the main features of this periodic table :

1. The elements are arranged in **rows** and **columns** in the periodic table.
2. The horizontal rows are called periods. There are six periods in the periodic table. These are numbered from 1 to 6 (Arabic numerals). Each one of the 4th, 5th and 6th periods have two series of elements.
3. Properties of elements in a given period show regular gradation (*i.e.* increase or decrease) from left to right.
4. The vertical columns present in it are called **groups**. There are eight groups numbered from **I** to **VIII** (Roman numerals).
5. Groups I to VII are further divided into A and B **subgroups**. However, group VIII contains three elements in each of the three periods.
6. All the elements present in a particular group are chemically similar in nature. They also show a regular gradation in their physical and chemical properties from top to bottom.

## Merits of Mendeleev's Periodic Classification

### 1. Classification of all elements

Mendeleev's classification included *all the 63 elements known* at that time on the basis of their atomic mass and facilitated systematic study of elements.

## 2. Correction of atomic masses

Atomic masses of some elements like Be (*beryllium*), Au (*gold*), In (*indium*) were corrected based on their positions in the table. (See box 1)

## 3. Prediction of new elements

Mendeleev arranged the elements in the periodic table in increasing order of atomic mass but whenever he could not find out an element with expected properties, he left a blank space. He left this space blank for an element yet to be discovered. He even predicted the properties of such elements and also of some of their compounds. For example, he predicted the existence of unknown element for the vacant space below silicon and thus belonging to the same group IV B, of the periodic table. He called it **eka-silicon** (meaning, *one position below silicon*). Later, in 1886, *C.A. Winkler* of Germany discovered this element and named it as **germanium**. The predicted and the actual properties of this element were remarkably similar (see Box 2). **Ekaboron** (scandium) **and eka-aluminium** (gallium) are two more examples of unknown elements predicted by Mendeleev.

**Box 1**

Indium had been assigned an atomic mass of 76 and valency of *two*. On the basis of its position in the periodic table, Mendeleef predicted its atomic mass to be 113.1 and its valency to be *three*. The accepted atomic mass today is 114.82 and valency is *three*.

**Box 2**

*Predictions for eka-silicon by Mendeleef*

| Property | Predicted eka-silicon | Actual Germanium |
|---|---|---|
| Atomic Mass | 72 | 72·6 |
| Density/g $cm^{-3}$ | 5·5 | 5·36 |
| Melting point | High | 1231K |
| Action of acid | Likely to be slightly attacked | No action with HCl, reacts with hot nitric acid |
| Action of alkali | No reaction | No action with dil. NaOH |
| Oxide | $MO_2$ | $GeO_2$ |
| Sulphide | $MS_2$ | $GeS_2$ |
| Chloride | $MCl_4$ | $GeCl_4$ |
| Boiling point of chloride | 373 K | 356 K |

## 4. Valency of elements

Mendeleev's classificaiton helped in understanding the valency of elements. The valency of elements is given by the group number. For example, all the elements in group 1 i.e. lithium, hydrogen, sodium, potassium, rubidium, caesium have valency 1.

## Defects of Mendeleev's Periodic Table

Mendeleev's periodic table was a great success, yet it had the following defects :

### 1. Position of Hydrogen

The position of hydrogen which is placed in group IA along with alkali metals is ambiguous as it resembles alkali metals as well as halogens (group VII A).

### 2. Position of Isotopes

All the isotopes of an element have different atomic masses therefore, each one of them should have been assigned a separate position. On the other hand, they are all chemically similar; hence they should all be placed at the same position. In fact, Mendeleev's periodic table did not provide any space for different isotopes. For example, two isotopes of carbon are represented as $_6C^{12}$, $_6C^{14}$ but placed at the same position.

### 3. Anomalous* Pairs of Elements

At some places, an element with greater atomic mass had been placed before an element with lower atomic mass due to their properties. For example, cobalt with higher atomic mass (58.9) was placed before nickel with lower atomic mass (58.7). Other such pairs are :

(i) Tellurium (127.6) is placed before iodine (126.9) and

(ii) Argon (39.9) is placed before potassium (39.1).

### 4. Grouping of chemically dissimilar elements

Elements such as copper and silver have no resemblance with alkali metals (lithium, sodium etc.), but have been grouped together in the first group.

### 5. Separation of chemically similar elements

Elements which are chemically similar such as gold and platinum have been placed in separate groups.

## INTEXT QUESTIONS 6.1

1. Elements A, B and C constitute a Dobereiner's triad. The atomic mass of A is 20 and that of C is 40. Predict the atomic mass of B.
2. Which property of atoms was used by Mendeleev to classify the elements?
3. In Mendeleev's periodic classification, whether chemically similar elements are placed in a group or in a period?

*Anomaly means deviation from common rule, irregularity, abnormal, exception

4. Mendeleev's periodic table had some blank spaces. What did they signify?
5. Explain any three defects of Mendeleev's periodic table.

## 6.2 MODERN PERIODIC LAW

Though Mendeleev's periodic table included all the elements, yet at many places a heavier element had to be placed before a lighter one. Such pairs of elements (*called anomalous pairs*) violated the periodic law. Also, there was no place for different isotopes of an element in the periodic table. Due to these reasons, it was felt that the arrangement of elements in the periodic table should be based on some other property which is more fundamental than the atomic mass.

In 1913, Henry Moseley, an English physicist discovered that the **atomic number** and not the atomic mass is the most fundamental property of an element.

***Atomic number*** *(Z) of an element is the number of protons in the nucleus of its atom.*

Since atom is as electrically neutral entity, the number of electrons is also equal to its atomic number i.e.the number of protons. After this development, it was felt necessary to change the periodic law and modify the periodic table.

### 6.2.1 Modern Periodic Law

*The **Modern Periodic Law** states that the chemical and physical properties of elements are periodic functions of their atomic numbers i.e. if elements are arranged in the order of their increasing atomic number, the elements with similar properties are repeated after certain regular intervals.*

Fortunately, even with the revised periodic law, the Mendeleev's classification did not require any major revision as it was based on properties of the elements. In fact, taking atomic number as the basis for classification, removed major defects from it such as a*nomalous pairs* and *position of isotopes.*

After changes in the periodic law, many modifications were suggested in the periodic table. Now, we shall learn about the modern periodic table in its final shape that is being used now..

### Cause of Periodicity

Let us now understand the cause of periodicity in the properties of elements. Consider the electronic configuration of alkali metals *i.e.*, the first group elements with atomic numbers 3, 11, 19, 37, 55 and 87 (*i.e.*, lithium, sodium, potassium, rubidium, caesium and francium) in the table given below:

**Table 6.4 : Electronic configuration of group 1 elements**

| Element | Electronic configuration |
|---|---|
| $_{3}Li$ | 2, 1 |
| $_{11}Na$ | 2, 8, 1 |
| $_{19}K$ | 2, 8, 8, 1 |
| $_{37}Rb$ | 2, 8, 18, 8, 1 |
| $_{55}Cs$ | 2, 8, 18, 18, 8, 1 |
| $_{87}Fr$ | 2, 8, 18, 32, 18, 8, 1 |

All these elements have one electron in the outer most shell and so they have similar properties which are as follows :

(i) They are good reducing agents.

(ii) They form monovalent cations.

(iii) They are soft metals.

(iv) They are very reactive and, therefore, found in nature in combined state.

(v) They impart colour to the flame.

(vi) They form hydrides with hydrogen.

(vii) They form basic oxides with oxygen.

(viii) They react with water to form metal hydroxides and liberate hydrogen.

It is noticed that all the elements having similar electronic configuration have similar properties. Thus, *the re-occurrence of similar electronic configuration is the cause of periodicity in properties of elements.*

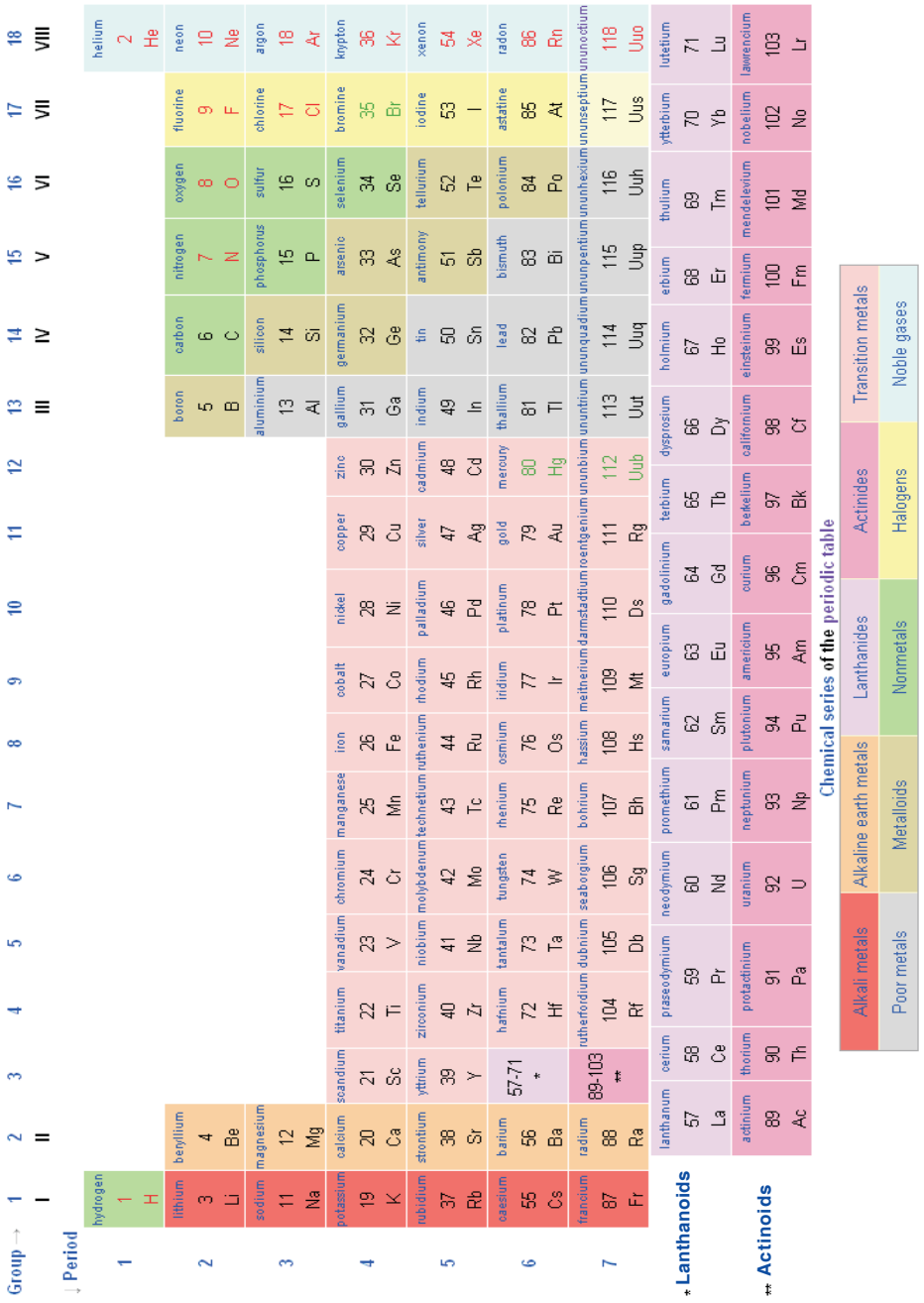
## 6.3 MODERN PERIODIC TABLE

The periodic table based on the modern periodic law is called the **Modern Periodic Table**. Presently, the accepted modern periodic table is the **Long Form of Periodic Table**.

It may be regarded as an extended form of Mendeleev's table in which the sub-groups A and B have been separated.

Now, you will learn the main features of the long form of periodic table which is shown in Table 6.5.

**Table 6.5 : Modern Periodic Table**




## 6.3.1 Features of Long Form of Periodic Table

The long form of periodic table helps us to understand the reason why certain elements resemble one another and why they differ from other elements in their properties. The arrangement of elements in this table is also in keeping with their electronic structures (configuration). In table 6.5, you must have noticed that it is divided into columns and rows. The columns represent the **groups** or family and the rows represent the **periods**.

1. **Groups:** There are 18 vertical columns in the periodic table. Each vertical column is called a **group**. The groups have been numbered from 1 to 18 (in Arabic numerals).

   All elements present in a group have similar electronic configurations and have same number of valence electrons. You can see in case of group 1 (alkali metals) and group 17 elements (halogens) that as one moves down a group, more and more shells are added as shown in Table 6.6.

**Table 6.6**

| Group 1 | | Group 17 | |
|---|---|---|---|
| **Element** | **Electronic configuration** | **Element** | **Electronic configuration** |
| Li | 2,1 | F | 2,7 |
| Na | 2,8,1 | Cl | 2,8,7 |
| K | 2,8,8,1 | Br | 2,8,8,7 |
| Rb | 2,8,18,8,1 | I | 2,8,18,18,7 |

All elements of group 1 have only one valence electron. Li has electrons in two shells, Na in three, K in four and Rb has electrons in five shells. Similarly all the elements of group 17 have seven valence electrons however the number of shells is increasing from two in fluorine to five in iodine.

2. **Periods:** There are *seven* horizontal rows in the periodic table. Each row is called a **period.** The elements in a period have consecutive atomic numbers. The periods have been numbered from 1 to 7 (in Arabic numerals).

   In each period a new shell starts filling up. The period number is also the number of the shell which starts filling up as we move from left to right across that particular period. For example, in elements of 3$^{rd}$ period (N = 3), the third shell (*M* shell) starts filling up as we move from left to right*. The first element of this period, sodium (Na 2,8,1) has only one electron in its valence shell (third shell) while the last element of this period, argon (Ar 2,8,8) has eight electrons in its valence shell. The gradual filling of the third shell can be seen below.

| Element<br>Period → | Na | Mg | Al | Si | P | S | Cl | Ar |
|---|---|---|---|---|---|---|---|---|
| Electronic configuration | 2,8,1 | 2,8,2 | 2,8,3 | 2,8,4 | 2,8,5 | 2,8,6 | 2,8,7 | 2,8,8 |

* However, it should be noted here that more and more electrons are added to valence shell only in case of normal elements. In transition elements, the electrons are added to incomplete inner shells.

(a) The first period is the *shortest period* of all. It contains only two elements; H and He.

(b) The second and third periods are called *short periods* containing 8 elements each.

(c) The fourth and fifth periods are *long periods* containing 18 elements each.

(d) The sixth and seventh periods are *very long periods* containing 32 elements each.

### 6.3.2 Types of Elements

1. **Main Group Elements:** The elements present in groups 1 and 2 on left side and groups 13 to 17 on the right side of the periodic table are called *representative* or *main group elements*. Their outermost shells are incomplete,which means their outermost shell has less than eight electrons.

2. **Noble Gases:** Group 18 on the extreme right side of the periodic table contains *noble gases*. Their outermost shells contain 8 electrons except He which contains only 2 electrons.

   Their main characteristics are :

   (a) They have 8 electrons in their outermost shell (except **He** which has 2 electrons).

   (b) Their combining capacity or valency is zero.

   (c) They do not react and so are almost inert.

   (d) All the members are gases.

3. **Transition Elements:** The middle block of periodic table (groups 3 to 12) contains *transition elements.* Their two outermost shells are incomplete.

   Since these elements represent a transition (change) from the most electropositive element to the most electronegative element, they are named as *transition elements*.

   Their important characteristics are as follows:

   (a) All these elements are metals and have high melting and boiling points.

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

   (c) Some of these elements get attracted towards magnet.

   (d) Most of these elements are used as catalyst.

   (e) They exhibit variable valencies.

4. **Inner Transition Elements:** These elements, also called *rare-earth elements,* are shown separately below the main periodic table. These are *two series of*

*14 elements each*. The first series called ***lanthanoids*** consists of elements 58 to 71 (Ce to Lu). They all are placed along with the element 57, *lanthanum* (La) in the same position (group 3, period 6) because of very close resemblance between them. It is only for the sake of convenience that they are shown separately below the main periodic table.

The second series of 14 rare-earth elements is called ***actinoids***. It consists of elements 90 to 103 (Th to Lr) and they are all placed along with the element 89, *actinium* (Ac) in the same position (group 3, period 7) but for convenience they are shown below the main periodic table.

In all rare-earths (lanthanoids and actinoids), *three outermost* shells are incomplete. They are therefore called *inner transition elements*.

It is interesting to note that the element lanthanum *is not* a lanthanoid and the element actinium *is not* an actinoid.

5. **Metals:** *Metals* are present in the left hand portion of the periodic table. The strong metallic elements; *alkali metals* (Li, Na, K, Rb, Cs, Fr) and *alkaline earth metals* (Be, Mg, Ca, Sr, Ba, Ra) occupy groups 1 and 2 respectively.
6. **Non-metals:** *Non-metals* occupy the right hand portion of the periodic table. Strong non-metallic elements *i.e.*, *halogens* (F, Cl, Br, I, At) and *chalkogens* (O, S, Se, Te, Po) occupy groups 17 and 16 respectively.
7. **Metalloids:** *Metalloids* are the elements that show mixed properties of both metals and non-metals. They are present along the diagonal line starting from group 13 (Boron) and going down to group 16 (Polonium).

## ACTIVITY 6.1

Rearrange the alphabets to get the correct name of the element in the space provided and mention its position in the modern periodic table

(a) RGANO ..... is a noble gas which is placed in group ..... and third period of the modern periodic table.

(b) HULIMIT ..... is an alkali metal which is placed in group 1 and ..... period of the modern periodic table.

(c) MILCUAC ..... is an alkaline earth metal which is placed in group ..... and fourth period of the modern periodic table.

(d) POHSROSUHP ..... is a metalloid which is placed in group 15 and ..... period of the modern periodic table.

### 6.3.3 Merits of the Modern Periodic Table

The following points overcame the defects of Mendeleev's periodic table, that is why, it was accepted by scientists across the world

1. **Position of isotopes:** All isotopes of an element have the same atomic number and therefore, occupy the same position in the modern periodic table.
2. **Anomalous pairs:** The anomaly regarding all these pairs disappears when *atomic number* is taken as the basis for classification. For example, cobalt (at. no. 27) would naturally come before nickel (at. no. 28) even though its atomic mass is little more than that of nickel.
3. **Electronic configuration:** This classification is according to the electronic configuration of elements, *i.e.,* the elements having a certain pattern of electronic configuration are placed in the same group of the periodic table. It relates the properties of elements to their electronic configurations. This point will be further elaborated in the next section.
4. **Separation of metals and non-metals:** The position of metals, non-metals and metalloids are clearly established in the modern periodic table.
5. **Position of transition metals:** It makes the position of the transition elements quite clear.
6. **Properties of elements:** It reflects the differences, the trends and the variations in the properties of the elements in the periodic table.
7. This table is simple, systematic and easy way of remembering the properties of dfifferent metals.

## INTEXT QUESTIONS 6.2

1. Give any two defects of Mendeleev's periodic table which has been removed in modern periodic table. How were they removed?
2. Metalloids are present along the diagonal line starting from group 13 and going down to group 16. Do they justify their position in the modern periodic table?

## 6.4 PERIODIC TRENDS IN PROPERTIES

You have learnt about the main features of the long form of the periodic table in the previous section.and you know that it consists of groups and periods. Let us recall their two important features:

1. In a given group, the number of filled shells increases. The number of valence electrons is the same in all the elements of a given group. However, these valence

electrons but they are present in higher shells which are farther away from the nucleus. In view of this, decreases the force of attraction between the outermost shell and the nucleus as we move downwards in a group.

2. In a given period, the nuclear charge and the number of valence electrons in a particular shell increase from left to right. This increases the force of attraction between the valence electron and nucleus as we move across a period from left to right.

The above given changes affect various properties which show gradual variations in groups and periods, and they repeat themselves after certain intervals of atomic number. They are called *periodic properties*. Now you are going to learn the variations of two of such properties in the periodic table.

## A. Atomic Size

*Atomic size is the distance between the centre of nucleus and the outermost shell of an isolated atom*. It is also known as *atomic radius*. It is measured in picometre, pm (1 pm = $10^{-12}$ m). Atomic size is a very important property of atoms because it is related to many other properties.

### Variation of atomic size in periodic table.

The size of atoms *decreases from left to right* **in a period** but *increases from top to bottom* **in a group**. For example, the atomic radii of the elements of the second period and of group 1 are given below in the tables 6.7 and 6.8 respectively.

**Table 6.7 : Atomic radii of period 2 elements**

| **Atomic Number** | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|
| **Elements : (in second period)** | Li | Be | B | C | N | O | F |
| **Atom radius/pm :** | 134 | 90 | 82 | 77 | 75 | 73 | 72 |
| **Atomic Size** | ◯ | ◯ | ○ | ○ | ○ | ○ | ○ |

In a period the atomic number and therefore the positive charge on the nucleus increases gradually. As a result, the electrons are attracted more strongly and they come closer to the nucleus. This decreases the atomic size in a period from left to right.

In a group as one goes down, a new shell is added to the atom which is farther away from the nucleus. Hence electrons move away from the nucleus. This increases the atomic size in a group from top to bottom.

**Table 6.8 : Atomic radii of group 1 elements**

| Atomic Number | Elements (in groups I) | Atom radius/pm | Atomic Size |
|---|---|---|---|
| 3 | Li | 134 |  |
| 11 | Na | 154 |  |
| 19 | K | 196 |  |
| 37 | Rb | 211 |  |
| 55 | Cs | 225 |  |

## B. Metallic and Non-metallic Character

The tendency of an element to lose electrons to form cations is called *electropositive or metallic character* of an element. Alkali metals are most electropositive. The tendency of an element to accept electrons to form anions is called *electronegative or non-metallic character* of an element.

### (a) Variation of Metallic Character in a Group

*Metallic character increases from top to bottom in a group as tendency* to lose electrons increases. This increases the electropositive character and metallic nature. The variation can best be seen in group 14 as shown below.

**Table 6.9: Metallic character of groups 14 elements**

| Element | Nature |
|---|---|
| C | Non-metal |
| Si | Metalloid |
| Ge | Metalloid |
| Sn | Metal |
| Pb | Metal |

### (b) Variation of Metallic Character in a Period

*Metallic character decreases in a period from left to right*. It is because the ionization energy increases in a period. This decreases the electropositive character and metallic nature. The variation of metallic character in the elements of 3rd period is shown below.



**Table 6.10 : Metallic character of 3rd period elements**

| **Element** | Na | Mg | Al | Si | P | S | Cl |
|---|---|---|---|---|---|---|---|
| **Nature** | Metal | Metal | Metal | Metalloid | Non-Metal | Non-Metal | Non-Metal |

In this section, you have learnt about variation of some properties in periodic table. Some important trends in periodic table may be summarized in a general way as given below :

**Table 6.11 : Variation of various periodic properties in periods and groups**

| Property | In a Period (From left to right) | In a Group (From top to Bottom) |
|---|---|---|
| Atomic number | increases | increases |
| Atomic size | decreases | increases |
| Metallic character | decreases | increases |
| Non-metallic character | increases | decreases |

## INTEXT QUESTIONS 6.3

1. Fill in the blanks with appropriate words

   (a) The force of attraction between nucleus and valence electrons ..... in a period from left to right.

   (b) Atomic radii of elements ..... in a period from left to right.

   (c) Atomic radii of elements ..... in a group from top to bottom.

   (d) Metallic character of elements ..... from top to bottom in a group.

2. In the following crossword puzzle, elements are present horizontally, vertically downwards and diagonally downwards. Let us find out how many elements you are able to get within 5 minutes.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Z | N | H | Y | D | R | O | G | E | N |
| M | B | I | C | A | R | B | O | N | O |
| A | D | E | T | B | A | R | I | U | M |
| G | X | Y | H | R | M | U | S | A | S |
| N | A | D | E | O | O | A | O | O | I |
| E | I | U | J | P | X | G | I | S | L |
| S | O | D | I | U | M | Y | E | L | I |
| I | D | M | U | X | A | I | G | N | C |
| U | I | O | M | O | G | E | Y | E | O |
| M | N | D | P | S | B | O | R | O | N |
| A | E | C | H | L | O | R | I | N | E |

Please check in the intext answers to find if you missed out any.

3. Let us find how many riddles you can solve.

   (i) I am the only noble gas whose outermost shell has 2 electrons. Who am I?

   (ii) I am placed in group 16 of the modern periodic table and essential for your respiration. Who am I?

   (iii) I combine with chlorine to form your table salt. Who am I?

   (**Hint:** Answers are present in the grid]

## WHAT YOU HAVE LEARNT

- The first classification of elements was as metals and non-metals.
- After the discovery of atomic mass (old term, atomic weight) it was thought to be the fundamental property of elements and attempts were made to correlate it to their other properties.
- John Dobereiner grouped elements into triads. The atomic mass and properties of the middle element were mean of the other two. He could group only a few elements into triads. For example (i) Li, Na and K (ii) Ca, Sr and Ba (iii) Cl, Br and I.

- Newlands tried to see the periodicity of properties and stated his law of octaves as "*When elements are arranged in the increasing order of their atomic weights every eighth element has properties similar to the first*". He could arrange elements up to calcium only out of more than sixty elements then known.
- Mendeleev observed the correlation between atomic weight and other properties and stated his periodic law as, "*The chemical and physical properties of elements are a periodic function of their atomic weights*".
- Mendeleev gave the first periodic table which is named after him which included all the known elements. It consists of seven horizontal rows called **periods** and numbered them from 1 to 7. It has eight vertical columns called **groups** and numbered them from I to VIII.
- Main achievements of Mendeleev's periodic table were (i) inclusion of all the known elements and (ii) prediction of new elements.
- Main defects of Mendeleev's periodic table were (i) position of isotopes, (ii) anomalous pairs of elements like Ar and K and (iii) grouping of dissimilar elements and separation of similar elements.
- Moseley discovered that atomic number and not atomic mass is the fundamental property of elements. In the light of this the periodic law was modified to "The *chemical and physical properties of elements are periodic functions of their atomic numbers*". This is the Modern Periodic Law.
- Modern Periodic Table is based upon atomic number. Its long form has been accepted by IUPAC. It has seven periods (1 to 7) and 18 groups (1 to 18). It is free of main defects of Mendeleev's periodic table. Elements belonging to same group have same number of valence electrons and thus show same valency and similar chemical properties.
- Arrangement of elements in the periodic table shows periodicity. Atomic radii and metallic character increase in a group from top to bottom and in a period decrease from left to right.

## TERMINAL EXERCISE

### A. *Objective questions*

### I. Mark the correct choice:

1. *Which one of the following was the earliest attempt of classification of elements?*

   (a) Classification of elements into metals and non-metals

   (b) Newlands' Law of Octaves

(c) Dobereiner's Triads

(d) Mendeleef's Periodic Table

2. *The 'law of octaves' was given by*

(a) Mendeleev (b) Newlands

(c) Lother Meyer (d) Dobereiner

3. *According to the periodic law given by Mendeleev, the properties of an element are a periodic function of its*

(i) atomic volume (ii) atomic size

(iii) atomic number (iv) atomic mass

4. *The particle which is universally present in the nuclei of all elements is*

(a) neutron (b) proton

(c) electron (d) α-particle

5. Potassium is more metallic than sodium because

(a) both have 1 electron in their outermost shell.

(b) both are highly electropositive.

(c) sodium is larger in size than potassium.

(d) potassium is larger in size than sodium.

7. Which one of the following elements in its chloride does not show the valence equal to its valence electrons?

(a) NaCl (b) $MgCl_2$

(c) $AlCl_3$ (d) $PCl_3$

8. Which one of the following elements has the least tendency to form cation?

(a) Na (b) Ca

(c) B (d) Al

9. Which one of the following does not belong to the family of the alkali metals?

(a) Li (b) Na

(c) Be (d) K

10. The number of elements in the $5^{th}$ period of the periodic table is

(a) 2 (b) 8

(c) 32 (d) 18

11. The elements with atomic number 9 resembles with the element having atomic number

(a) 35 (b) 27

(c) 17 (d) 8

12. In which period of the periodic table, an element with atomic number 20 is placed?

(a) 4 (b) 3

(c) 2 (d) 1

## II. Mark the following statements *True* (T) or *False* (F) :

1. The properties of the middle element in a Dobereiner's triads are intermediate between those of the other two.
2. The vertical columns in the periodic table are called periods.
3. Mendeleev depended only on the atomic mass of elements for his classification.
4. All elements present in a group are chemically similar.
5. The modern periodic law is based upon atomic mass.
6. The importance of atomic number as the fundamental property was realised by Henry Mosely.
7. There are 18 groups in the modern periodic table.
8. Non-metals are present in the middle portion of the periodic table.
9. Each period in modern periodic classification begins with filling of electrons in a new shell.

## III. Fill in the blanks:

1. According to the modern periodic law, the properties of elements are periodic function of their .....
2. The ..... number is same as the number of shell which in gradually filled up in the elements of this period.
3. In normal elements of a particular period the electrons are gradually filled in ..... shell.
4. All elements of a particular group have ..... electronic configurations.
5. In the modern periodic table, groups are numbered from ..... to .....
6. The second and third periods of the periodic table are called ..... periods.
7. The main group elements are present in group 1 and 2 on the left side and ..... to ..... on the right side of the periodic table.

8. All the group eighteen elements (except the first one) contain ..... valence electrons.
9. All transition elements are metals with ..... melting and boiling points.
10. The group of 14 rare-earth elements belonging to the group 3 and $7^{th}$ period are called .....
11. All elements present in a given ..... have the same valency.
12. Atomic size ..... in a period from left to right.
13. Magnesium is ..... metallic than calcium.
14. Carbon belongs to group ..... of the Periodic table.
15. All the elements of group 15 have ..... valence electrons.

## B. *Subjective Questions*

### I. Very short Answer Questions (Answer in one word or one sentence).

1. What was the earliest classification of elements?
2. State Newlands' law of octaves.
3. Which classification of elements failed after the discovery of noble gases?
4. State Mendeleev's Periodic Law.
5. How were the groups numbered in the Mendeleev's periodic table?
6. Name the fundamental properties of element on which the modern periodic law is based.
7. How many groups are there in the modern periodic table?
8. How have groups been numbered in the modern periodic table?
9. What are normal elements?
10. What are the elements present in the middle portion of the modern periodic table called?
11. What is atomic size?
12. How does atomic size vary in a period and in a group?
13. Where would the element with largest atomic size be placed in any group?
14. Give the number of a group in which metallic, metalloid and non-metallic, all three types of elements, are present.

### II. Short Answer Questions (Answer in 30-40 words).

1. State Dobereiner's law of triads.
2. Show that chlorine, bromine and iodine (atomic masses 35·5, 80 and 127 respectively) constitute a triad.

3. What were the reasons for the failure of Newlands' law of octaves ?
4. Describe Mendeleev's periodic table briefly in terms of rows and columns and their raw being.
5. Give any two achievements of the Mendeleev's Periodic classification.
6. What were the defects in Mendeleev's periodic classification.
7. State modern periodic law.
8. Briefly describe the modern periodic table in term of groups and period.
9. Give names of four classes into which the elements have been classified and mention to which groups of the modern period table they belong.
10. List the merits of the long form of the modern periodic table and explain any two of them.
11. How are the electronic configurations of all the elements belonging to a particular group related? Explain with the help of group 17 elements.
12. How does the electronic configuration of elements belonging to a particular period vary? Explain with the example of second period elements.
13. Define atomic radius.
14. How and why does metallic character vary in a group from top to bottom?

## III. Long Answer Questions (Answer in 60–70 words).

1. State Mendeleev's Periodic Law and describe the periodic table constructed on this basis.
2. What are the merits and demerits of the Mendeleev's Periodic classification?
3. Describe the modern periodic table in terms of groups and periods.
4. What are the following types of elements and where are they located in the periodic table?

   (a) Main group elements (b) Noble gases

   (c) Transition elements (d) Inner transition elements.
5. Discuss the merits of the modern periodic table.
6. What is the relationship between the electronic configuration and the modern periodic table?
8. Explain the variation of atomic size in a group and in a period.
9. How is metallic character related to ionization energy ? Explain the variation of metallic character in the periodic table.

## ANSWERS TO INTEXT QUESTIONS

### 6.1

1. Atomic mass of B = $\frac{20 + 40}{2} = 30$
2. Atomic mass
3. Group
4. These were the positions of elements which were yet to be discovered.
5. Any three of the following: (i) position of hydrogen (ii) position of isotopes (iii) anomalous pairs of elements (iv) grouping of chemically dissimilar element (v) separation of chemically similar element (vi) no explanation for electronic configuration

### 6.2

1. Anomalous pairs when elements are arranged in the order of their increasing atomic numbers, these anomalies are automatically removed, since the atomic number of the first element is less than that of the second although their atomic masses show revrse trends.
2. Position of isotopes. Since all the isotopes of an element have the same atomic number, they all will occupy the same position in the periodic table.

### 6.3

1. (a) increases (b) decreases
   (c) increases (d) increases
2. Hydrogen, Carbon, Barium, Sodium, Boron, Chlorine (horizontally)
   Magnesium, Iodine, Helium, Neon, Silicon, (vertically downwards)
   Nitrogen, Oxygen(diagonally downwards)
3. (i) Helium (ii) Oxygen (iii) Sodium

### Activity 6.1

(a) Argon (b) Lithium (c) Calcium (d) Phosphorous