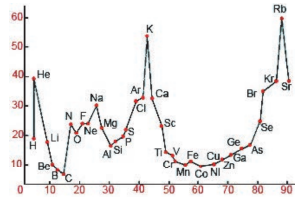
CHAPTER 4

PERIODIC CLASSIFICATION OF ELEMENTS



Matter is present all around us and it can be classified into elements, compounds or mixtures. Did we always classify substances in this way? Take the case of elements. The history of elements is very interesting and it took a very long time for scientists to understand which substances were elements and which were not.

4.1 Elements – then and now

According to the philosopher Aristotle (384-322 BC), the universe is made up of five elements namely fire, water, air, earth and ether. Many centuries later, a British scientist Robert Boyle (1627-1691) also did a number of experiments related to matter. On the basis of his experiments he concluded that the five elements described by Aristotle were not actually elements.

In 18^{th} century, a French scientist Lavoisier defined an element as a substance that could not be decomposed or broken down into simpler substances. For example, we know that water can be broken down into hydrogen and oxygen, therefore, it is not an element. Lavoisier prepared a list of 33 elements on the basis of his experiments but today 118 elements are known. It is very difficult to individually explore so many elements and their properties. Scientists have tried to solve this problem in many ways so that elements can be easily studied.

4.2 Why arrange elements?

We are always trying to arrange objects on the basis of their properties and use. For example, in our homes, we keep the clothes which we wear in one place. Other clothes such as bed-sheets, pillow covers are also kept together but separate from the clothes we wear. Even in the clothes that we wear, we keep winter clothes separate from summer clothing.

Think, when you go to a grocery shop and ask the shop-keeper for an item, how is he able to locate it easily among the different objects? Organizing objects saves us time and energy. That is why scientists too made many attempts to organize elements based on their properties.

In class 9^{th} we learnt about atomic number, atomic weight and electronic configuration of elements. Some elements are given in table-1 along with their atomic numbers and atomic weight.

(a) Arrange the elements in table-1 in increasing order of their atomic weights.

(b) Arrange the elements in table-1 in increasing order of their atomic numbers.

Table-1

Element	Atomic weight	Atomic number	Element	Atomic weight	Atomic number
S	32.1	16	B	10.8	5
Li	6.9	3	P	31	15
Al	27	13	Ca	40.1	20
O	16	8	Ne	22.2	10
Ar	39.9	18	C	12	6
Be	9	4	Cl	35.5	17
H	1	1	Na	23	11
Si	28.08	14	N	14	7
F	19	9	Mg	24.3	12
He	4	2	K	39.1	19

- Did you get the same order of elements in both the cases?
- Write the electronic configurations of the given elements.
- Can we group the elements based on their electronic configuration?

By now, you must have realized why we try to arrange and organize elements and that there can be more than arrangement. Let us try to understand the attempts made by some scientists in the past to classify elements.

4.3 Döbereiner's Law of Triads

The German scientist, Döbereiner, classified elements on the basis of their atomic weights. When he placed three elements having similar properties one below the other in increasing order of their atomic weights, he found that the atomic weight of the middle element was nearly the average of the atomic weights of the other two elements. The three elements formed a group known as a triad.

J.W. Döbereiner (1780-1849)

Johann Wolfgang Döbereiner trained as a pharmacist at Münchberg in Germany, and then studied chemistry at Strasbourg. Döbereiner was the first person to identify the catalytic properties of platinum. He also identified triads of similar elements which later led to the development of the Periodic Table of elements.

Li 6.9
Na 23
K 39.1

For example, he took the triad consisting of potassium, lithium and sodium and found that the atomic weight of sodium is almost equal to the average of the atomic weights of lithium and potassium. Its properties also lie somewhere between the properties of lithium and potassium. Döbereiner proposed a law based on this observation of relation between properties of elements and their atomic weights. According to Döbereiner's law of triads, when three elements having similar properties are written in the order of their increasing atomic weights the atomic mass of the middle element is the average of the atomic weights of the remaining two elements and its properties lie in the middle of the two. Döbereiner could form only three triads from the elements known at that time (Table-2).

The law proved true in the case of very few elements therefore this method of classifying elements into triads was not successful.

As soon as people saw the similarity between elements based on their atomic weights, other attempts were made to organize elements. Newlands also made one such attempt.

Table-2 : Döbereiner's triads

Triads of elements		
I	II	III
Li	Ca	C1
Na	Sr	Br
K	Ba	I

4.4 Newlands' Law of Octaves

Do you know?

In the Indian system of music, the seven musical are- *sa, re, ga, ma, pa,da, ni*.

Western music uses the notes- *do, re, mi, fa, so, la, ti*.

Every eighth note is similar to the first one and it is the first note of the next scale. The notes are used for composing music.

Through Döbereiner attempts, other chemists also noticed the correlation between the properties of elements and their atomic weights. In this series, the British scientist John Alexander Newlands (1837-1898) gave the law of octaves according to which when elements are arranged in increasing order of their atomic weights, then the properties of every eighth element were similar to those of the first. He compared this to the octaves (eight notes) seen in music and therefore the law is known as law of octaves. He put hydrogen, having the lowest atomic weight, at the first position and ended with the element thorium at the 56^{th} position.

Table-3: Newlands' Octaves

Notes in Indian music system	*sa*	*re*	*ga*	*ma*	*pa*	*dh*	*ni*
Notes in Western music system	*do*	*re*	*mi*	*fa*	*so*	*la*	*ti*
Elements	H F Cl	Li Na K	Be Mg Ca	B A1 Cr	C Si Ti	N P Mn	O S Fe

In Newlands' Octaves, the properties of fluorine were similar to those of hydrogen and fluorine was the eighth element after hydrogen. Similarly, the properties of lithium and sodium were similar.

There were many limitations with Newlands' octaves, for example -

- It could accommodate only 56 elements and did not have any place for new elements.
- It was found that the Law of Octaves was applicable only upto calcium, as after calcium the eighth element did not possess properties similar to that of the first.
- Newlands put some unlike elements in the same group. Iron was placed with oxygen and sulphur although its properties were very different from them.

Thus, Newlands' law too was unsuccessful in classifying all elements.

Questions

1. Look at the given table and answer:

Group 'A'	Element	Li	?	K
	Atomic mass	6.9	23.0	39.1
Group 'B'	Element	Ca	Sr	Ba
	Atomic mass	40.1	?	137.3
Group 'C'	Element	C1	Br	I
	Atomic mass	35.5	?	126.9

(i) Which element will lie in the middle of group ´A´?

(ii) What will be the atomic weight of the middle element in group ´B´?

(iii) What will be the atomic weight of the middle element in group ´C´?

2. What are the limitations of Döbereiner's classification?

3. Look at table-3 and identify the elements that sodium will resemble.

4.5 Lothar Meyer's atomic volume curve

The German scientist Lothar Meyer plotted a graph of atomic volume of an element against its atomic weight. He observed that the elements sodium, potassium and rubidium were located on the peaks on the graph and fluorine, chlorine and bromine were situated in the rising portions of the curve. Metals such as magnesium, calcium etc. were located on descending portions of the curve and beryllium, boron, carbon, aluminium etc. were situated on the minima of the curve (figure-1).

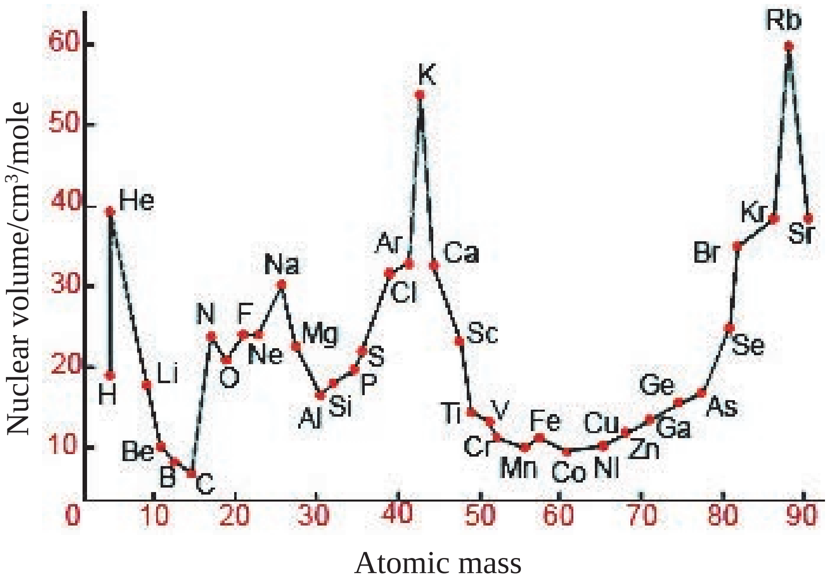


Figure-1 : Lothar Meyer's atomic volume curve

On this basis, he noticed that elements having similar properties were situated at similar locations on the curve, that is, the atomic volumes of the elements are periodic functions of their atomic weights.

While Lothar Meyer was working on classification of elements on the basis of atomic weights and atomic volumes, his contemporary Mendeleev presented a simpler classification based on the atomic weights and physical and chemical properties of elements. Meyer's use of the term periodic function gave direction to Mendeleev and helped him develop his version of the periodic table.

4.6 Mendeleev's classification

The major credit for classifying elements goes to a Russian chemist, Dmitri Ivanovich Mendeléev. He was an important contributor in the early development of a Periodic Table of elements. When Mendeléev started his work, 63 elements were known. He studied the relationship between the atomic weights of the elements and their physical and chemical properties. In chemical properties, Mendeléev focused on the compounds formed by elements with oxygen and hydrogen. He selected hydrogen and oxygen as they are very reactive and formed compounds with most elements.

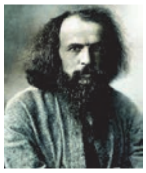
Mendeléev took 63 cards and on each card he wrote down the properties of one element. When he grouped together the elements with similar properties he found that most of the elements were arranged in the order of their increasing atomic weights. He arranged the elements in the form of a table where elements having similar properties were placed one below the other.

He also observed that the elements with similar properties occur after a fixed interval. On this basis, Mendeléev formulated a Periodic Law, which states that 'the properties of elements are the periodic function of their atomic masses'. In Mendeleev's periodic table, the vertical columns were called groups and the horizontal rows were called periods (figure-2).

Group	I	II	III	IV	V	VI	VII	VIII
Oxide Hydride	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

Figure-2: Mendeléev’s periodic table

Dmitri Ivanovich Mendeléev (1834-1907)



The Russian chemist Mendeléev is known as the father of periodic table. In addition, he contributed towards the modernization of Russian chemical and mining industries. He also proposed a theory regarding the formation of petroleum. His efforts to develop a new method of teaching chemistry resulted in an organized form of the periodic table.

Mendeléev's periodic table was first published in a German journal in 1872. At the top of each column, the general formula for oxides and hydrides were given where the letter 'R' was used to represent any of the elements in the group. For example, the hydride of carbon, CH_4, is written as RH_4 and the oxide CO_2, as RO_2. Mendeléev decided the location of an element in a group based on the chemical compounds formed by it. He used the formulae of the compounds to determine their valency. The number given to a group showed its valency in relation to oxygen. For example, if the formula of the compound of an element was R_2O it was placed in the first group and if the formula was RO it was placed in the second group. Can you tell what will be formula of an oxide from group three?

In this way, the valences of the first, second and third group are 1, 2 and 3 respectively.

4.6.1 Achievements of Mendeléev's periodic table

a. Used in the study of elements: Periodic changes are observed in the properties of elements within the same period in the periodic table. At the same time, similarities are seen in the properties of elements belonging to the same group. Therefore, if we know the properties of one element of a group we can easily find out the properties of other elements of that group. Thus, Mendeléev's periodic table is useful in the study of elements.

b. Useful in discovery of new elements: Mendeléev left some gaps in his Periodic Table. Instead of looking upon these gaps as defects, Mendeléev predicted the existence of some elements that had not been discovered at that time. Mendeléev named them by prefixing Eka to the name of preceding element in the same group. For instance, scandium, gallium and germanium, discovered later, were called Eka-boron, Eka-aluminium and Eka-silicon, respectively.

c. Corrections in disputed atomic weights: The atomic weight of beryllium was corrected on the basis of its valency in Mendeléev's periodic table. It was considered divalent rather than trivalent and placed between lithium and boron. Similarly, the atomic weights of the elements indium, euronium etc. were also corrected.

d. Space for inert gases: Inert gases such as helium, neon and argon had not been discovered during Mendeleev's times so no space was kept in the periodic table for them. When they were discovered, they were placed in a separate column which was added to the periodic table as the zero group by the scientist Ramsay.

4.6.2 Limitations of Mendeléev's periodic table

a. Uncertainty in hydrogen's position: Hydrogen gives H^+ ions similar to those (K^+, Li^+) given by alkali metals and like the ions formed by halogens (Cl^-, Br^-), it can also form H^- ion. Therefore, it difficult to decide the correct group in which hydrogen should be placed.

b. Placing heavier elements before lighter elements: When elements were arranged according to valency, in some places heavier elements were placed before lighter elements in violation of Mendeleev's rule. For example, cobalt (atomic weight 58.9) was placed before nickel (atomic weight 58.7).

c. Positioning of isotopes: We know that isotopes of the same element have same chemical properties but different atomic weights. According to Mendeleev's law, each isotope should have been given a separate position but Mendeleev's periodic table did not have any space for isotopes.

d. Irregular increase in atomic weights when moving from one element to the next: Since the atomic weights did not increase in a regular manner when going from one element to the next, it was difficult to predict how many elements could be discovered between two elements - especially when we consider the heavier elements.

Questions

1. What was the basis of classification of elements as done by Lothar Meyer?
2. Write the names and symbols of the first four elements found in groups I and II of Mendeleev's periodic table?
3. Some spaces were left empty in Mendeleev's periodic table. Write the names of the elements that were later placed in these gaps.
4. Name the two elements whose atomic weights were corrected by Mendeleev.
5. Why were inert gases placed in a separate group? Write the reasons.

The limitations of Mendeleev's periodic table were overcome in the 20th century with the discovery of sub-atomic particles and a better understanding of the structure of the atom.

4.7 Moseley's modern periodic law

British scientist, Henry Moseley (1887-1915) studied the X-ray spectrum of different elements. He observed that the wavelength of X-rays emitted by an element was related to its position number in Mendeleev's periodic table. Atomic weights of elements were known when Mendeleev proposed his periodic table. Another characteristic of elements, which was named atomic number, was discovered through Moseley's work. Atomic number is a fundamental property and gives the number of protons present in the nucleus of an atom of any element. On the basis of his results, Moseley suggested that atomic number rather than atomic weight should be the property used in the classification of elements. He showed that the chemical properties of elements depend on their electronic configuration which is decided by the atomic number of the element. Therefore, he modified Mendeleev's periodic law and gave the modern periodic law in 1913. According to the modern periodic law, the physical and chemical properties of the elements are periodic functions of their atomic numbers.

The modern periodic table

Key: 1 — atomic number; H — Symbol; Hydrogen — Name; 1.0 — atomic mass

metals | metalloids | Non-metals | noble gases (inert) | Research ongoing

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.0																	2 He Helium 4.0
3 Li Lithium 6.9	4 Be Beryllium 9.0											5 B Boron 10.8	6 C Carbon 12.0	7 N Nitrogen 14.0	8 O Oxygen 16.0	9 F Fluorine 19.0	10 Ne Neon 20.2
11 Na Sodium 23.0	12 Mg Magnesium 24.3											13 Al Aluminium 27.0	14 Si Silicon 28.1	15 P Phosphorus 31.0	16 S Sulfur 32.1	17 Cl Chlorine 35.5	18 Ar Argon 39.9
19 K Potassium 39.1	20 Ca Calcium 40.1	21 Sc Scandium 44.9	22 Ti Titanium 47.9	23 V Vanadium 50.9	24 Cr Chromium 52.0	25 Mn Manganese 54.9	26 Fe Iron 55.8	27 Co Cobalt 58.9	28 Ni Nickel 58.7	29 Cu Copper 63.5	30 Zn Zinc 65.4	31 Ga Gallium 69.7	32 Ge Germanium 72.6	33 As Arsenic 74.9	34 Se Selenium 79.0	35 Br Bromine 79.9	36 Kr Krypton 83.8
37 Rb Rubidium 85.5	38 Sr Strontium 87.5	39 Y Yttrium 88.9	40 Zr Zirconium 91.2	41 Nb Niobium 92.9	42 Mo Molybdenum 95.9	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Caesium 132.9	56 Ba Barium 137.3	57 La Lanthanum 138.9 *	72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227) **	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (267)	110 Ds Darmstadtium (281.2)	111 Rg Roentgenium (282.2)	112 Cn Copernicium (285.2)	113 Nh Nihonium (286.2)	114 Fl Flerovium (289.2)	115 Mc Moscovium (289.2)	116 Lv Livermorium (293.2)	117 Ts Tennessine (294.2)	118 Og Oganesson (294.2)

The number given in brackets ( ) is the atomic mass of the isotope of the element having the longest half life.

Lanthanides*	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinides**	90 Th Thorium 232.0	91 Pa Protactinium (231)	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (254)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

Figure-3: Modern periodic table

4.8 Modern Periodic Table

Bohr used Moseley's law to organize elements into a table where they were placed in ascending order of their atomic numbers. This table was called Bohr's periodic table. The 92 naturally occurring elements known at that time were placed in the table. This periodic table is also known as the modern periodic table or the long form of periodic table (figure-3). The elements that come after atomic number 92 (till atomic number 118) have been chemically synthesized and have been given space in the modern periodic table.

The long form of periodic table has 18 (vertical) columns known as groups and 7 horizontal rows called periods.

Group – In Mendeleev's periodic table, the group number of an element is decided by its valency but in modern periodic table, it is decided by the electronic configuration.

- Elements found in groups 1,2,13,14,15,16,17 and 18 are called main group elements.
- Elements found in groups 3-12 are called transition elements.

In group 3, the 14 elements that come after lanthanum (La, atomic number 57) are placed in a separate panel below the periodic table and are called lanthanides. Similarly in group 3, the 14 elements that come after actinium (Ac, atomic number 89) are placed in a panel below the periodic table and are called actinides. They are displayed below the periodic table so that it takes a more convenient form.

Period – In the modern periodic table, the numbers of shells of all elements belonging to a particular period is equal.

On moving from left to right in a period, the atomic numbers of the elements increase by one and the number of valence electrons also increases by one. The number of valence electrons are different in lithium, beryllium, boron, carbon, nitrogen etc. and therefore they are members of different groups but because the numbers of shells occupied is same for all, they are placed in the same period. Can you tell the number of the period to which they belong?

We can tell the number of elements present in each period by calculating the maximum number of electrons that can occupy a shell. We know that the maximum number of electrons that can be placed in a shell is calculated using the formula $2n^2$ where n = shell number.

For example, for the first period, the maximum number of electrons in n = 1 (K shell) is $2\times(1)^2 = 2$. Therefore, the first period has 2 elements.

Using the calculation given above, can you tell how many elements will be present in the third period? If we calculate the maximum number of electron in the m shell, we get 18. But we also know that according to Bohr-Bury rule, the maximum number of electrons in the outermost shell cannot be more than 8. Since M is the outermost shell here, therefore it cannot have more than 8 electrons and this is the reason why the number of elements in the third period is 8.

In the periods after this, the number of electrons in a shell is decided by some other rules which we will study in higher classes.

- The first three periods of the modern periodic table are known as short periods and have 2,8 and 8 elements respectively.
- The two periods after the first three are called long periods and both have 18 elements each.
- The sixth period has 32 elements and with the discovery of 4 new elements, the seventh period also has 32 elements.

4.8.1 Characteristics of the Modern periodic table

- The periodic table is based on atomic number.
- The position of each element has been decided based on its electronic configuration.
- Periodic changes in properties of elements are shown more clearly.
- Because hydrogen is capable of forming both negative (H^-) and positive (H^+) ions, it is similar to the elements of both group 17 (which give negative ions) and of group 1 (which give positive ions). Therefore, similar to Mendeleev's periodic table, the position of hydrogen in the modern periodic table is also not fixed. However, usually hydrogen is placed at the top of group 1.

Questions

1. According to the modern periodic table, the properties of an element are a periodic function of what?
2. What will be the number of elements in the second period?
3. Can you fix the position of different isotopes of an element in the modern periodic table? Explain.
4. How have the positions of argon and potassium been determined in the modern periodic table?
5. If the atomic number of three elements x, y and z are 6, 10 and 18 respectively then:
   (a) Which of the two elements belong to the same group?
   (b) Which of the two elements belong to the same period?

4.8.2 Periodic properties of elements

According to the periodic law, when elements are arranged in increasing order of their atomic number, their properties show periodicity. Periodic variation in electronic configuration with increase in atomic number is the reason for this periodicity in properties.

When we move down a group or from left to right in a period then we observe a periodic variation in the physical and chemical properties of elements. Let us study some periodic properties.

1. Valency

Valency is an important property of elements. We can understand valency on the basis of electronic configurations of elements. Valency is the number of electrons present in the outermost shell of an element or the number of electrons needed to complete the octet. Now, can you tell how valency will change when we move down a group or from left to right in a period? Let us understand by looking at table-4 which shows the elements of second period and their respective hydrides.

Table-4: Periodic variation in the valency of the elements of second period

Element	Li	Be	B	C	N	O	F	Ne
Hydride	LiH	BeH2	BH3	CH4	NH3	H2O	HF	-
Valency	1	2	3	4	3	2	1	0

In the second period of the periodic table, the valency of elements relative to hydrogen first increases from one to four and then decreases to zero.

Questions

1. How will you calculate the valency of an element given its electronic configuration?
2. How does valency change when we move down a group?

2. Atomic size

The size of atoms of different elements is also different. Their sizes can be compared using the values of their atomic radii. Atomic radii implies the distance between the centre of the nucleus and the outermost shell of an atom.

Table-5 shows the atomic radii of the elements of group 17. Arrange them in increasing order and answer the following questions:

1. Which elements have the largest and the smallest atoms?
2. How does the atomic radius change we move down a group?

Table-5: Some atomic radii

Elements of group 17	Atomic radii (pm)
Br	114
F	64
I	133
Cl	99
At	144

We find that atomic size increases on moving down a group. This is because a new shell is added as we go down which increases the distance between the nucleus and the outermost shell.

Table-6 shows the atomic radii of elements belonging to the third period.

Table-6: Atomic radii of elements of the third period

Elements of the third period	Na	Mg	Al	Si	P	S	Cl
Atomic radii (pm)	186	160	143	117	110	104	99

- How does the atomic radius change as you go from left to right in a period?

We see that the atomic radius decreases in moving from left to right along a period. This is due to an increase in nuclear charge which tends to pull the electrons closer to the nucleus and reduces the size ofthe atom.

3. Metallic and Non-metallic Properties

118 elements have been discovered so far. Each element has some characteristic properties which are used to classify them into two groups – metals and non-metals.

Table-7: Elements of the second period

Second period	Li	Be	B	C	N	O	F
Atomic number	3	4	5	6	7	8	9

Look at table-7 and tell:-

- Which elements will form negative ions and which will form positive ions?
- On which side of the Periodic Table do you find the metals and on which side do you find the non-metals?
- How do the metallic and non-metallic properties change as we move from left to right?

We know that elements which lose electrons to form positive ions are called metals, for example, iron, zinc, sodium etc. Those that accept electrons to form negative ions are called non-metals, for example, oxygen, chlorine etc. Let us understand better through some more examples.

In the Modern Periodic Table, a zig-zag line separates metals from non-metals. The borderline elements - boron, silicon, germanium,arsenic, antimony, tellurium and polonium - exhibit the properties of both metals and non-metals and are called metalloids or semi-metals.

On observing the periodic table we find that there is an increase in metallic character and decrease in non-metallic properties as we move down a group.

- Think: Do these properties also change in a period?

4. Ionization energy/ ionization potential

The energy required to remove the most loosely held electron from an isolated gaseous atom is called ionization potential or ionization energy. To obtain an isolated atom, first the solid or liquid element is converted into its gas state and if the element is in its molecular form then it is first broken into its constituent atoms. The unit for ionization energy is electron volt.

Let us see the electronic configurations of the elements of the first group.

Table-8: Electronic configuration of elements of first group

Element	Atomic number	electronic configuration
H	1	1
Li	3	2,1
Na	11	2,8,1
K	19	2,8,8,1

When we move from hydrogen to potassium, along with increase in number of electrons, the number of shells also increases and so does the distance between the nucleus and the outermost electron. This is the reason why less energy is needed to remove the outermost electron. Thus, the value of ionization energy decreases as we move down a group.

Now, let us see the second period.

Table-9: Ionization energy of elements of second period

Element	Li	Be	B	C	N	O	F	Ne
Ionization Energy (eV)	5.6	9.9	8.3	11.3	14.5	13.6	17.4	21.6

Is there any change in the shell number as we move from lithium towards neon? We find that number of shells is two (K and L) in all cases but the atomic number is increasing leading to increase in nuclear charge. Thus, due to increased nuclear attraction more energy is needed to remove the electrons in the outermost shell.

Questions

1. How does the ionization energy change in a group?
2. How does the ionization energy of elements belonging to the same period vary? Explain why?

5. Electron affinity

We know that metals can give up electrons to form positive ions. Elements of groups 1 and 2 have respectively 1 and 2 electrons in their outermost shells. They lose these electrons to form monovalent (+1) and divalent (+2) ions. These elements are located on left side of the periodic table.

On the right side of the periodic table we have non-metals which accept electrons to form negative ions. When one electron is added to any atom, it acquires a negative charge with release of energy. The energy released is called electron affinity.

Generally, as we move from left to right in a period, the value of electron affinity increases and it decreases as we move down a group.

6. Electronegativity

If a covalent bond exists between two different types of atoms, then one of the atoms has a greater tendency than the other atom to attract the electron pair towards itself. For example, HCl molecule has one pair of shared electrons. Here, as compared to the hydrogen atom the chlorine atom attracts the shared electron pair towards itself. Therefore, the electron pair is closer to the chlorine atom. The atom that attracts the shared electron pair towards itself is more electronegative and it acquires a partial negative charge.

The tendency or ability of an atom in a chemical compound to attract shared electrons to itself (and thus gain a partial negative charge) is called electronegativity.

Generally, as we move from left to right in a period, the value of electronegativity increases and it decreases as we move down a group.

Electron affinity and electronegativity are different from each other. Electronegativity is the property of an atom to attract the shared electron pair in a covalent bond with another atom towards itself. Therefore, it is a relative quantity which does not have a unit whereas electron affinity is the energy released when an electron is added to an isolated gaseous atom and its unit is eV.

Questions

1. How does electron affinity differ from electronegativity?
2. The elements of which group have the highest electron affinities?

What we have learnt

- Elements are classified on the basis of similarities in their properties.
- Efforts to organize and classify elements had begun even before Dalton gave his atomic theory in 1808 but his theory gave a new direction to other scientists by showing that there is a relation between the atomic weight of an element and its properties.
- Döbereiner arranged elements having similar properties into groups of three called triads.
- Newlands gave the law of octaves to classify elements and compared this to musical notes.
- Lothar Meyer used the term periodic while describing the property of elements and this directed Mendeleev's efforts in developing his periodic table.
- Mendeléev arranged the elements in increasing order of their atomic weights.
- Mendeléev left gaps in his Periodic Table that helped predict the existence of some yet to be discovered elements.
- Moseley gave the modern periodic law based on atomic numbers.
- The Modern Periodic Table has 18 vertical columns called groups and 7 horizontal rows called periods in which 118 elements have been arranged according to their electronic configuration.
- Different properties of elements – such as valency, atomic size, metallic and non-metallic character, ionization energy, electron affinity and electronegativity – show a periodic variation across groups and periods.
- Periodicity in the properties of elements is due to the periodic variation in the electronic configurations of outermost shells.

Keywords

Law of triads, law of octaves, periodic function, periodicity, atomic size, atomic radii, ionization potential, electron affinity, electronegativity

Exercises

1. Choose the correct option–
   - (i) The position of which of the following elements is not fixed in the periodic elements
     - (a) Sodium (b) Chlorine
     - (c) Helium (d) Hydrogen
   - (ii) Elements in Mendeleev's periodic table have been arranged according to–
     - (a) Increasing order of molecular weight
     - (b) Increasing order of atomic weight
     - (c) Increasing order of atomic number
     - (d) Increasing order of atomic radii
   - (iii) The modern periodic law was proposed by–
     - (a) Newlands (b) Moseley
     - (c) Mendeleev (d) Döbereiner
   - (iv) On moving down a group, the metallic character–
     - (a) Neither increases nor decreases (b) decreases
     - (c) Increases (d) First increases, then decreases
   - (v) Which of the following depicts increasing atomic sizes of Na, Li, K –
     - (a) Li<Na<K (b) K<Na<Li
     - (c) Na<Li<K (d) None of the above
2. The physical and chemical properties of elements belonging to the same group are similar, why?
3. Hydrogen should be placed in which group and which period? Give reasons.
4. In each of the given pairs, choose which element will have the bigger atom. Give reasons for your choice.
   - (a) Mg (atomic number 12) or Cl (atomic number 17)
   - (b) Na (atomic number 11) or K (atomic number 19)
5. The atomic numbers of three elements A, B and C are 5, 7 and 10 respectively. Which two of these will have similar properties? Give reasons.

6. The atomic numbers of three elements are 5, 7 and 10 respectively. Which of these:
   (a) Belongs to group 18
   (b) Belongs to group 15
   (c) Belongs to group 13
7. 'A', 'B' and 'C' are three elements that form a triad. If the atomic weight of 'A' is 7 and that of 'C' is 39 then according to Döbereiner's rule of triads what will be the atomic weight of 'B'?
8. The figure shows a part of the periodic table:
   If we move horizontally from left to right

Li	Be	B	C	N	O	F
Na	Mg	Al	Si	P	S	Cl

   (i) How does the metallic character of the elements change?
   (ii) How does electronegativity change?
   (iii) How does electron affinity change?
9. Why did Mendeleev leave gaps in his periodic table? Use an example to illustrate your answer.
10. Are Döbereiner's triads seen in Newlands' octets? Compare and write.
11. Give the trends shown by the following properties when we go down a group or from left to right in a period in the modern periodic table – valency, atomic size, ionization potential, electronegativity
12. The electronic configuration of an element B is 2, 8, 7 and it forms an ionic compound AB_2 with another element A. What is the valency of element A?
13. Compare the arrangement of elements in Mendeleev's periodic table and the modern periodic table.