MODULE - 2 Matter in our Surroundings
Chapter-06

PERIODIC CLASSIFICATION OF ELEMENTS

CLASSIFICATION OF ELEMENTS

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.

There after 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

Dobereiner's Triads

Scientist : Dobereiner, a German chemist(1829)

Proposal: 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.**
"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."

Table 6.1: Dobereiner's triads of elements

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

Newlands' Law of Octaves

Scientist : John Alexander Newlands (1864)

Proposal: When he 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.**

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

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

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.

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.

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.

Mendeleev's Periodic Law and Periodic Table

Scientist : D'mitri Mendeleev (1869)

Proposal: 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**.

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.**

The success of Mendeleev's classification was--------→laid more emphasis on the properties of elements rather than on atomic masses

Table 6.3: Mendeleev's updated periodic table

Groups	I	II	III	IV	V	VI	VII	VIII
Oxides Hydrides	RO 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

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.

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.

4. Valency of elements –

Mendeleev's classification 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

1. Position of Hydrogen

The position of hydrogen which is **placed in group 1A 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 6C12, 6C14 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 group**s.

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.

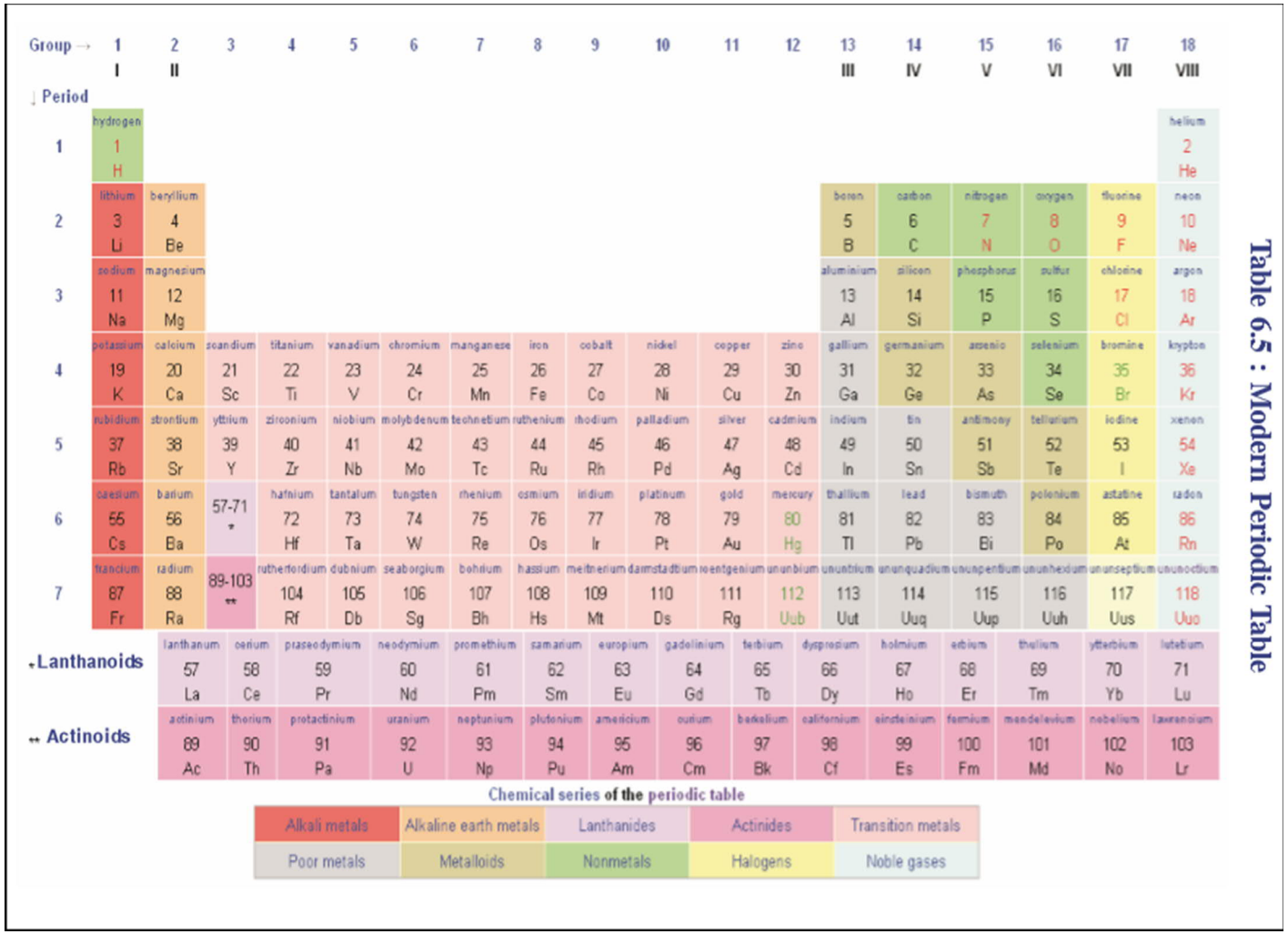
- ✓ In 1913, **Henry Moseley**, an English physicist **discovered that the atomic number is most fundamental property of an element not the atomic mass .**

- ✓ 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.

" **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."

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".**



Group →	1 I	2 II	3	4	5	6	7	8	9	10	11	12	13 III	14 IV	15 V	16 VI	17 VII	18 VIII
↓ Period																		
1	hydrogen 1 H																	helium 2 He
2	lithium 3 Li	beryllium 4 Be											boron 5 B	carbon 6 C	nitrogen 7 N	oxygen 8 O	fluorine 9 F	neon 10 Ne
3	sodium 11 Na	magnesium 12 Mg											aluminium 13 Al	silicon 14 Si	phosphorus 15 P	sulfur 16 S	chlorine 17 Cl	argon 18 Ar
4	potassium 19 K	calcium 20 Ca	scandium 21 Sc	titanium 22 Ti	vanadium 23 V	chromium 24 Cr	manganese 25 Mn	iron 26 Fe	cobalt 27 Co	nickel 28 Ni	copper 29 Cu	zinc 30 Zn	gallium 31 Ga	germanium 32 Ge	arsenic 33 As	selenium 34 Se	bromine 35 Br	krypton 36 Kr
5	rubidium 37 Rb	strontium 38 Sr	yttrium 39 Y	zirconium 40 Zr	niobium 41 Nb	molybdenum 42 Mo	technetium 43 Tc	ruthenium 44 Ru	rhodium 45 Rh	palladium 46 Pd	silver 47 Ag	cadmium 48 Cd	indium 49 In	tin 50 Sn	antimony 51 Sb	tellurium 52 Te	iodine 53 I	xenon 54 Xe
6	caesium 55 Cs	barium 56 Ba	57-71 *	hafnium 72 Hf	tantalum 73 Ta	tungsten 74 W	rhenium 75 Re	osmium 76 Os	iridium 77 Ir	platinum 78 Pt	gold 79 Au	mercury 80 Hg	thallium 81 Tl	lead 82 Pb	bismuth 83 Bi	polonium 84 Po	astatine 85 At	radon 86 Rn
7	francium 87 Fr	radium 88 Ra	89-103 **	ruthenfordium 104 Rf	dubnium 105 Db	seaborgium 106 Sg	bohrium 107 Bh	hassium 108 Hs	meitnerium 109 Mt	darmstadtium 110 Ds	roentgenium 111 Rg	ununbium 112 Uub	ununtrium 113 Uut	ununquadium 114 Uuq	ununpentium 115 Uup	ununhexium 116 Uuh	ununseptium 117 Uus	ununoctium 118 Uuo
* Lanthanoids	lanthanum 57 La	cerium 58 Ce	praseodymium 59 Pr	neodymium 60 Nd	promethium 61 Pm	samarium 62 Sm	europium 63 Eu	gadolinium 64 Gd	terbium 65 Tb	dysprosium 66 Dy	holmium 67 Ho	erbium 68 Er	thulium 69 Tm	ytterbium 70 Yb	lutetium 71 Lu			
** Actinoids	actinium 89 Ac	thorium 90 Th	protactinium 91 Pa	uranium 92 U	neptunium 93 Np	plutonium 94 Pu	americium 95 Am	curium 96 Cm	berkelium 97 Bk	californium 98 Cf	einsteinium 99 Es	fermium 100 Fm	mendelevium 101 Md	nobelium 102 No	lawrencium 103 Lr			

Chemical series of the periodic table

Alkali metals	Alkaline earth metals	Lanthanides	Actinides	Transition metals
Poor metals	Metalloids	Nonmetals	Halogens	Noble gases

Table 6.5 : Modern Periodic Table

Cause of Periodicity

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.

Table 6.4 : Electronic configuration of group 1 elemen

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

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 columns represent the groups or family and the rows represent the periods.

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.

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

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).

Element 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

(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.

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 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(1-2): Metals are present in the left hand portion of the periodic table. The strong metallic elements;
alkali metals (Li, Na, K, Rb, Cs, Fr) - groups 1
alkaline earth metals (Be, Mg, Ca, Sr, Ba, Ra)- groups 2

6. Non-metals(16-17) 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(13-6): 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).

Merits of the Modern Periodic Table

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.
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 different metals**

PERIODIC TRENDS IN PROPERTIES

In a given group the number of filled shells increases when move from Top to Bot.

In view of this, decreases the force of attraction between the outermost shell and the nucleus as we move downwards in a group.

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.

1. 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.**

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	◯	◯	◯	◯	◯	◯	◯

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	◯

2.Metallic and Non-metallic Character.

The tendency of an element to lose electrons to form **cations** is called **electropositive or metallic character .**

The tendency of an element to accept electrons to form **anions** is called **electronegative or non-metallic character.**

a. Metallic character increases from top to bottom in a group as tendency to lose electrons increases.
b. Metallic character decreases in a period from left to right.

Table 6.9: Metallic character of groups 14 elements

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

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

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

29. (a) What is the relationship between electronic configuration of elements present in a group and a period of modern periodic table ? Explain. **6**

(b) Explain the variation of (i) atomic size and (ii) metallic character in a group and in a period of modern periodic table.

(a) आधुनिक आवर्त सारणी के एक वर्ग और एक आवर्त में स्थित तत्वों के इलेक्ट्रानिक विन्यास के बीच क्या संबंध हैं ? व्याख्या कीजिए।

(b) आवर्त और वर्ग में (i) परमाणु आकार और (ii) धात्विक प्रकृति की आवर्तिता की व्याख्या कीजिए।

19. How does modern periodic law differ from Mendeleev's periodic law ? Explain any two defects of Mendeleev's periodic table which were overcome in the modern periodic table. **4**

आधुनिक आवर्त-नियम, मेन्डेलीव के आवर्त-नियम से किस प्रकार भिन्न है ? मेन्डेलीव की आवर्त सारणी के किन्हीं दो दोषों की व्याख्या कीजिए जिनका आधुनिक आवर्त सारणी में निदान हो गया है।

6 Which of the given elements A, B, C, D and E with atomic number 2, 3, 7, 10 and 30 respectively belong to the same period ? 1

(A) A, B, C (B) B, C, D

(C) A, D, E (D) B, D, E

दिए गए तत्वों A, B, C, D तथा E (परमाणु क्रमांक क्रमशः 2, 3, 7, 10 तथा 30) में से समान आवर्त्त के तत्व हैं

(A) A, B, C (B) B, C, D

(C) A, D, E (D) B, D, E

28 (a) State modern periodic law. Discuss the merits of the modern periodic table with reference to the following points : 6

(i) Position of isotopes.

(ii) Anomalous pairs.

(iii) Electronic configuration.

(b) Given below are some of the elements of the second period with their atomic radii :

Element	C	O	Li	N	F	Be	B
Atomic radius (pm)	77	73	134	75	72	90	82

Arrange these elements in order of their positions in the periodic table.