

UNIT

12

Periodic Classification of Elements

Learning Objectives



After completing this lesson, students will be able to

- know the concept of classification of elements in early days.
- understand the postulates, advantages and limitations of modern periodic table.
- understand the classification of elements based on the electronic configuration.
- learn about the position of hydrogen in the periodic table.
- study about the position of rare gases (Noble gases) in the periodic table.
- distinguish between metals and non-metals.
- know about metalloids and alloys.

Introduction

We live in the world of substances with great diversity. Substances are formed by the combination of various elements. All the elements are unique in their nature and property. To categorize these elements according to their properties, scientists started to look for a way. In 1800, there were only 31 known elements. By 1865, their number became 63. Now 118 elements have been discovered. As different elements were being discovered, scientists gathered more and more information about the properties of these elements. They found it difficult to organize all that was known about the elements. They started looking for some pattern in their properties, on the basis of which they could study such a large number of elements with ease. Let us discuss the concepts of classification of elements proposed by various scientists from early to modern period.

12.1. Early Concepts of Classification of Elements

12.1.1. Dobereiner's Triads

In 1817, Johann Wolfgang Dobereiner, a German chemist, suggested a method of grouping elements based on their relative atomic masses. He arranged the elements into groups containing three elements each. He called these groups as 'triads' (tri – three).

Dobereiner showed that **when the three elements in a triad are arranged in the ascending order of their atomic masses, the atomic mass of the middle element is nearly the same as average of atomic masses of other two elements.** This statement is called the Dobereiner's law of triads. Table 12.1 shows the law of triads proposed by Dobereiner.

Example: In the triad group (1), arithmetic mean of atomic masses of 1st and 3rd elements,



Table 12.1 Dobereiner's law of triads

Triad Group (1)		Triad Group (2)		Triad Group (3)	
Element	Atomic Mass	Element	Atomic Mass	Element	Atomic Mass
Li	6.9	Cl	35.5	Ca	40.1
Na	23	Br	79.9	Sr	87.6
K	39.1	I	126.9	Ba	137.3

$(6.9 + 39.1)/2 = 23$. So the atomic mass of Na (middle element) is 23.

Limitations:

- Dobereiner could identify only three triads from the elements known at that time and all elements could not be classified in the form of triads.
- The law was not applicable to elements having very low and very high atomic mass.

12.1.2 Newlands' Law of Octaves

In 1866, John Newlands arranged 56 known elements in the increasing order of their atomic mass. He observed that every eighth element had properties similar to those of the first element like the eighth note in an octave of music is similar to the first. This arrangement was known as 'law of octaves'.

The octave of Indian music system is sa, re, ga, ma, pa, da, ni, sa. The first and last notes of this octave are same i.e. sa. Likewise, in the Newlands' table of octaves, the element 'F' is eighth from the element 'H', thus they have similar properties.

Activity 1

Find the pair of elements having similar properties by applying Newlands' law of Octaves (Example: Mg & Ca):

Set I : F, Mg, C, O, B

Set II: Al, Si, S, Cl, Ca

Limitations:

- ❖ There are instances of two elements being fitted into the same slot, e.g. cobalt and nickel.

- ❖ Some elements, totally dissimilar in their properties, were fitted into the same group. (Arrangement of Co, Ni, Pd, Pt and Ir in the row of halogens)
- ❖ The law of octaves was not valid for elements that had atomic masses higher than that of calcium.
- ❖ Newlands' table was restricted to only 56 elements and did not leave any room for new elements.
- ❖ Discovery of inert gases (Neon, Argon....) at later stage made the 9th element similar to the first one. Eg: Neon between Fluorine and Sodium.

12.1.3 Mendeleev's Periodic Table

In 1869, Russian chemist, Dmitri Mendeleev observed that the elements of similar properties repeat at regular intervals when the elements are arranged in the order of their atomic masses. Based on this, he proposed the law of periodicity which states that "the physical and chemical properties of elements are the periodic functions of their atomic masses". He arranged 56 elements known at that time according to his law of periodicity. This was best known as the short form of periodic table.

(a) Features of Mendeleev's Periodic Table:

- ❖ It has eight vertical columns called 'groups' and seven horizontal rows called 'period'.
- ❖ Each group has two subgroups 'A' and 'B'. All the elements appearing in a group were found to have similar properties.
- ❖ For the first time, elements were comprehensively classified in such a way that elements of similar properties were placed in the same group.



Table 12.2 Newland's table of octaves (oct- eight)

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

- ❖ It was noticed that certain elements could not be placed in their proper groups in this manner. The reason for this was wrongly determined atomic masses. Consequently those wrong atomic masses were corrected. Eg: The atomic mass of beryllium was known to be 14. Mendeleev reassessed it as 9 and assigned beryllium a proper place.
- ❖ Columns were left vacant for elements which were not known at that time and their properties also were predicted. This gave motivation to experiment in Chemistry. Eg: Mendeleev gave names Eka Aluminium

and Eka Silicon to those elements which were to be placed below Aluminium and Silicon respectively in the periodic table and predicted their properties. The discovery of Germanium later on, during his life time, proved him correct.

(b) Limitations:

- ❖ Elements with large difference in properties were included in the same group. Eg: Hard metals like copper (Cu) and silver (Ag) were included along with soft metals like sodium (Na) and potassium (K).

Table 12.3 Mendeleev's Periodic Table

Group	I	II	III	IV	V	VI	VII	VIII
Oxide:	R ₂ O	RO	R ₂ O ₃	RO ₂	R ₂ O ₅	RO ₃	R ₂ O ₇	RO ₄
Hydride:	RH	RH ₄	RH ₄	RH ₄	RH ₃	RH ₂	RH	
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 18.988	
3	Na 22.99	Mg 22.99	Al 24.31	Si 28.09	P 30.974	S 32.06	Cl 35.453	
4 First Series	K 39.102	Ca 40.08	Sc 44.96	Ti 47.90	V 50.94	Cr 50.20	Mn 54.94	Fe 55.85
Second series	Cu 63.54	Zn 65.54	Ga 69.72	Ge 72.59	As 74.92	Se 78.96	Br 79.909	Co 58.93
5 First Series	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc 99	Ru 101.07
Second series	Ag 107.87	Cd 112.40	In 114.82	Sn 118.69	Sb 121.60	Te 127.60	I 126.90	Rh 102.91
6 First Series	Cs 132.90	Ba 137.34	La 138.91	Hf 178.40	Ta 180.95	W 183.85		Pd 106.4
Second series	Au 196.97	Hg 200.59	Tl 204.37	Pb 207.19	Bi 208.98			Os 190.2
7	Rn 222	Fr 223	Ra 226	Ac 227	Th 232	Pa 231	U 238	Ir 192.2
								Pt 195.05

- ❖ No proper position could be given to the element hydrogen. Non-metallic hydrogen was placed along with metals like lithium (Li), sodium (Na) and potassium (K).
- ❖ The increasing order of atomic mass was not strictly followed throughout. Eg. Co & Ni, Te & I.
- ❖ No place for isotopes in the periodic table.

Table 12.4 Properties of Germanium

Property	Mendeleev's prediction (1871)	Actual property (1886)
Atomic Mass	About 72	72.59
Specific Gravity	5.5	5.47
Colour	Dark grey	Dark grey
Formula of Oxide	EsO ₂	GeO ₂
Nature of Chloride	EsCl ₄	GeCl ₄

12.2 Modern Periodic Table

In 1913, the English Physicist Henry Moseley, through his X-ray diffraction experiments, proved that the properties of elements depend on the atomic number and not on the atomic mass. Consequently, the modern periodic table was prepared by arranging elements in the increasing order of their atomic number.

This modern periodic table is the extension of the original Mendeleev's periodic table and known as the long form of periodic table.

12.2.1 Modern Periodic Law

Atomic number of an element (Z) indicates the number of protons (positive charge) or the number of electrons (negative charge). The physical and chemical properties of elements depend not only on the number of protons but also on the number of electrons and their arrangements (electronic

configuration) in atoms. Hence, the modern periodic law can be stated as follows: “**The chemical and physical properties of elements are periodic functions of their atomic numbers**”. Based on the modern periodic law, the modern periodic table is derived.

12.2.2 Features of Modern Periodic Table

- All the elements are arranged in the increasing order of their atomic number.
- The horizontal rows are called periods. There are seven periods in the periodic table.
- The elements are placed in periods based on the number of shells in their atoms.
- Vertical columns in the periodic table starting from top to bottom are called groups. There are 18 groups in the periodic table.
- Based on the physical and chemical properties of elements, they are grouped into various families.

Table 12.5 Groups in modern periodic table

Group	Families
1	Alkali metals
2	Alkaline earth metals
3 to 12	Transition metals
13	Boron Family
14	Carbon Family
15	Nitrogen Family
16	Oxygen Family (or) Chalcogen Family
17	Halogens
18	Noble gases

12.2.3 Classification of elements into blocks

We know that the electrons in an atom are accommodated in shells around the nucleus. Each shell consists of one or more subshells in which the electrons are distributed in certain

PERIODIC TABLE OF THE ELEMENTS

GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
PERIOD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H 1.008 HYDROGEN IA																	He 4.0026 HELIUM VIIIA
2	Li 6.94 LITHIUM IIA	Be 9.0122 BERYLLIUM IIA																Ne 20.180 NEON VIIIA
3	Na 22.990 SODIUM IIA	Mg 24.305 MAGNESIUM IIA																Ar 39.948 ARGON VIIIA
4	K 39.098 POTASSIUM IA	Ca 40.078 CALCIUM IIA	Sc 44.956 SCANDIUM IIIB	Ti 47.867 TITANIUM IVB	V 50.942 VANADIUM VB	Cr 51.996 CHROMIUM VIB	Mn 54.938 MANGANESE VIIB	Fe 55.845 IRON VIII	Co 58.933 COBALT VIII	Ni 58.693 NICKEL VIII	Cu 63.546 COPPER IB	Zn 65.38 ZINC IIB	Ga 69.723 GALLIUM IIIB	Ge 72.64 GERMANIUM IV	As 74.922 ARSENIC VA	Se 78.971 SELENIUM VIA	Br 79.904 BROMINE VIIA	Kr 83.798 KRYPTON VIIIA
5	Rb 85.468 RUBIDIUM IA	Sr 87.62 STRONTIUM IIA	Y 88.906 YTTORIUM IIIB	Zr 91.224 ZIRCONIUM IVB	Nb 92.906 NIOBIUM VB	Mo 95.95 MOLYBDENUM VIB	Tc 98.906 TECHNETIUM VIIB	Ru 101.07 RUTHENIUM VIII	Rh 102.91 RHODIUM VIII	Pd 106.42 PALLADIUM VIII	Ag 107.87 SILVER IB	Cd 112.41 CADMIUM IIB	In 114.82 INDIUM IIIB	Sn 118.71 TIN IV	Sb 121.76 ANTIMONY VA	Te 127.60 TELLURIUM VIA	I 126.90 IODINE VIIA	Xe 131.29 XENON VIIIA
6	Cs 132.91 CAESIUM IA	Ba 137.33 BARIUM IIA	La-Lu 57-71 Lanthanide	Hf 178.49 HAFNIUM IVB	Ta 180.95 TANTALUM VB	W 183.84 TUNGSTEN VIB	Re 186.21 RHENIUM VIIB	Os 190.23 OSMIUM VIII	Ir 192.22 IRIDIUM VIII	Pt 195.08 PLATINUM VIII	Au 196.97 GOLD IB	Hg 200.59 MERCURY IIB	Tl 204.38 THALLIUM IIIB	Pb 207.2 LEAD IV	Bi 208.98 BISMUTH VA	Po 209 POLONIUM VIA	At 210 ASTATINE VIIA	Rn 222 RADON VIIIA
7	Fr 223 FRANCIUM IA	Ra 226 RADIUM IIA	Ac-Lr 89-103 Actinide	Rf 261 RUTHERFORDIUM IVB	Db 262 DUBNIUM VB	Sg 263 SEABORGIUM VIB	Bh 264 BOHRIIUM VIIB	Hs 265 HASSIUM VIII	Mt 266 MEITNERIUM VIII	Ds 269 DARMSTADTIUM VIII	Rg 270 ROENTGENIUM IB	Cn 271 COPECNICIUM IIB	Nh 272 NIHONIUM IIIB	Fl 274 FLEROVIUM IV	Mc 275 MOSCOVIUM VA	Lv 276 LIVERMORIUM VIA	Ts 277 TENNESSINE VIIA	Og 278 OGANESSON VIIIA

LANTHANIDE

ACTINIDE

57	La LANTHANUM	58	Ce CERIUM	59	Pr PRASEODYMIUM	60	Nd NEODYMIUM	61	Pm PROMETHIUM	62	Sm SAMARIUM	63	Eu EUROPIUM	64	Gd GADOLINIUM	65	Tb TERBIUM	66	Dy DYSPROSIUM	67	Ho HOLMIUM	68	Er ERBIUM	69	Tm THULIUM	70	Yb YTTERIUM	71	Lu LUTETIUM
89	Ac ACTINIUM	90	Th THORIUM	91	Pa PROTACTINIUM	92	U URANIUM	93	Np NEPTUNIUM	94	Pu PLUTONIUM	95	Am AMERICIUM	96	Cm CURIUM	97	Bk BERKELEYIUM	98	Cf CALIFORNIUM	99	Es EINSTEINIUM	100	Fm FERMIUM	101	Md MENDELEVIUM	102	No NOBELIUM	103	Lr LAWRENCIUM



manner. These subshells are designated as s, p, d, and f. Based on the arrangement of electrons in subshells, the elements of periodic table are classified into four blocks namely s, p, d and f blocks.

(1) s-Block Elements: It includes group 1 (alkali metals) and group 2 (alkaline earth metals) elements. They are also called as representative elements. The elements of group 1 (except hydrogen) are metals. They react with water to form solutions that change the colour of a vegetable dye from red to blue. These solutions are said to be highly alkaline or basic. Hence they are called alkali metals.

The elements of group 2 are also metals. They combine with oxygen to form oxides, formerly called 'earths', and these oxides produce alkaline solutions when they are dissolved in water. Hence, these elements are called alkaline earth metals.

(2) p-Block Elements: These elements are in group 13 to 18 in the periodic table. They include boron, carbon, nitrogen, oxygen, fluorine families in addition to noble gases (Except helium). They are also called as representative elements. The p-block is home to the biggest variety of elements and is the only block that contains all three types of elements: metals, nonmetals, and metalloids.

(3) d-Block Elements: It includes group 3 to group 10 elements. They are found in the centre of the periodic table. Their properties are intermediate to that of s block and p block elements and so they are called transition elements.

(4) f – Block Elements: It includes 14 elements after (Lanthanum) La (57), called Lanthanoides and 14 elements after (Actinium) Ac (89), called Actinoides. They are placed at the bottom of the periodic table. They are also called as inner Transition elements.

12.2.4 Advantages of the Modern Periodic Table

- The table is based on a more fundamental property i.e., atomic number.
- It correlates the position of the element with its electronic configuration more clearly.
- The completion of each period is more logical. In a period, as the atomic number increases, the energy shells are gradually filled up until an inert gas configuration is reached.
- It is easy to remember and reproduce.
- Each group is an independent group and the idea of subgroups has been discarded.
- One position for all isotopes of an element is justified, since the isotopes have the same atomic number.
- The position of the eighth group (in Mendeleev's table) is also justified in this table. All transition elements have been brought in the middle as the properties of transition elements are intermediate between left portion and right portion elements of the periodic table.
- The table completely separates metals from nonmetals. The nonmetals are present in upper right corners of the periodic table.
- The positions of certain elements which were earlier misfit (interchanged) in the Mendeleev's periodic table are now justified because it is based on atomic number of the elements.
- Justification has been offered for placing lanthanides and actinides at the bottom of the periodic table.

12.2.5 Position of hydrogen in the periodic table

Hydrogen is the lightest, smallest and first element of the periodic table. Its electronic configuration ($1s^1$) is the simplest of all the elements. It occupies a unique position in the periodic table. It behaves like alkali metals as well as halogens in its properties.



Table 12.6 Number of electrons in subshell

Shell number (Symbol)	1 (K)	2 (L)		3 (M)			4 (N)			
Sub shell	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f
Maximum number of electrons in each sub shell	2	2	6	2	6	10	2	6	10	14
Maximum number of electrons in each shell	2	8		18			32			

In the periodic table, it is placed at the top of the alkali metals.

- (i) Hydrogen can lose its only electron to form a hydrogen ion (H^+) like alkali metals.
- (ii) It can also gain one electron to form the hydride ion (H^-) like halogens.
- (iii) Alkali metals are solids while hydrogen is a gas.

Hence the position of hydrogen in the modern periodic table is still under debate as the properties of hydrogen are unique.

12.2.6. Position of Rare Gases

The elements Helium, Neon, Argon, Krypton, Xenon and Radon of group 18 in the periodic table are called as Noble gases or Rare gases. They are monoatomic gases and do not react with other substances easily, due to completely filled subshells. Hence they are called as inert gases. They are found in very small quantities and hence they are called as rare gases.

12.3 Metals, Non-Metals and Metalloids

12.3.1 Metals

Metals are typically hard, shiny, malleable (can be made as sheet), fusible and ductile (can be drawn into wire) with good electrical and thermal conductivity. Except mercury, most of the metals are solids at room temperature. Metals occupy larger area in the periodic table and are categorized as:

- (i) Alkali metals. e.g. Lithium to Francium (top to bottom)
- (ii) Alkaline earth metals. e.g: Beryllium to Radium (top to bottom)
- (iii) Transition Metals. Group III B to II A
- (iv) P-Block metals. e.g: Al, Ga, In, Tl, Sn, Pb and Bi.

4.3.2. Non-metals

A non-metal is an element that does not have the characters like hardness, shiny, malleable, suitable and ductile. In other words, a non-metal is an element that does not have the properties of metal. e.g. All non metals are arranged in P-Block only. P-Block non metals: C, N, O, P, S, Se, Halogen (F, Cl, Br and I) and inert gases (He to Rn).

12.3.3 Metalloids

Elements which have the properties of both metals and non-metals are called as metalloids. (eg) Boron, Arsenic.

12.4 Alloys

During 3500 BC(BCE), people used an alloy named 'bronze'. The idea of making an alloy was quite old. The majority of the metallic substances used today are alloys.



Alloys are mixtures of two or more metals and are formed by mixing molten metals thoroughly. Rarely nonmetals are also mixed with metals to produce alloys.

It is generally found that alloying produces a metallic substance that has more useful properties than the original pure metals from which it is made. For example, the alloy brass is made from copper and zinc.

12.4.1 Advantages of alloys

- Alloys do not get corroded or get corroded to very less extent.
- They are harder and stronger than pure metals (Example: Gold is mixed with copper and it is harder than pure gold).
- They have less conductance than pure metals (Example: Copper is good conductor of heat and electricity whereas brass and bronze are not good conductors).
- Some alloys have lower melting point than pure metals (Example: Solder is an alloy of lead and tin which has lower melting point than each of the metals).
- When metal is alloyed with mercury, it is called amalgam.

Points to Remember

- Dobereiner grouped the elements based on their relative atomic masses in a group of three (triads).
- John Newlands arranged 56 known elements in the increasing order of their atomic mass.
- Dmitri Mendeleev proposed the law of periodicity.
- Mendeleev's Periodic Table has eight vertical columns called 'groups' and seven horizontal rows called 'period'.
- In the modern periodic table all the elements are arranged in the increasing order of their atomic number.
- There are seven periods and 18 groups in the periodic table.
- The elements are placed in periods based on the number of shells in their atoms.
- Based on the common characteristics of elements in each group, they are grouped as various families.

A-Z GLOSSARY

Dobereiner's Law of Triads

The atomic mass of the middle element is nearly the same as average of atomic masses of other two elements.

Newlands' Law of Octaves

Every eighth element had properties similar to those of the first element like the eighth note in an octave of music is similar to the first.

Mendeleev's Law of Periodicity

The physical and chemical properties of elements are the periodic functions of their atomic masses.

Modern Periodic Law

The chemical and physical properties of elements are the periodic functions of their atomic numbers.

Periods

Horizontal rows in the modern periodic table.

Columns

Vertical columns in the modern periodic table

s block elements

Elements whose valence electrons are added to s subshell.

p block elements

Elements whose valence electrons are filled in p subshells.

d block elements

Elements having their valence electrons in the d subshells.

f block elements

Elements having their valence electrons in the f subshells.



TEXTBOOK EXERCISES



I. Choose the correct answer.

- If Dobereiner is related with 'law of triads', then Newlands is related with
 - Modern periodic law
 - Hund's rule
 - Law of octaves
 - Pauli's Exclusion principle
- Modern periodic law states that the physical and chemical properties of elements are the periodic functions of their _____
 - atomic numbers
 - atomic masses
 - similarities
 - anomalies
- Elements in the modern periodic table are arranged in _____ groups and _____ periods.
 - 7, 18
 - 18, 7
 - 17, 8
 - 8, 17
- Metals can gain electrons.
- Alloys bear the characteristics of both metals and nonmetals.
- Lanthanides and actinides are kept at the bottom of the periodic table because they resemble each other but they do not resemble with any other group elements.
- Group 17 elements are named as Halogens.

II. Fill in the blanks.

- In Dobereiner's triads, the atomic weight of the middle element is the _____ of the atomic masses of 1st and 3rd elements.
- Noble gases belong to _____ group of the periodic table.
- The basis of the classifications proposed by Dobereiner, Newlands and Mendeleev was _____.
- Example for liquid metal is _____.

III. Match the following.

Triads	Newlands
Alkali metal	Calcium
Law of octaves	Henry Moseley
Alkaline earth metal	Sodium
Modern Periodic Law	Dobereiner

IV. State whether true or false. If false, correct the statement.

- Newlands' periodic table is based on atomic masses of elements and modern periodic table is based on atomic number of elements.

V. Assertion and Reason.

Statement: Elements in a group generally possess similar properties but elements along a period have different properties.

Reason: The difference in electronic configuration makes the element differ in their chemical properties along a period.

- Statement is true and reason explains the statement.
- Statement is false but the reason is correct.

VI. Answer the following.

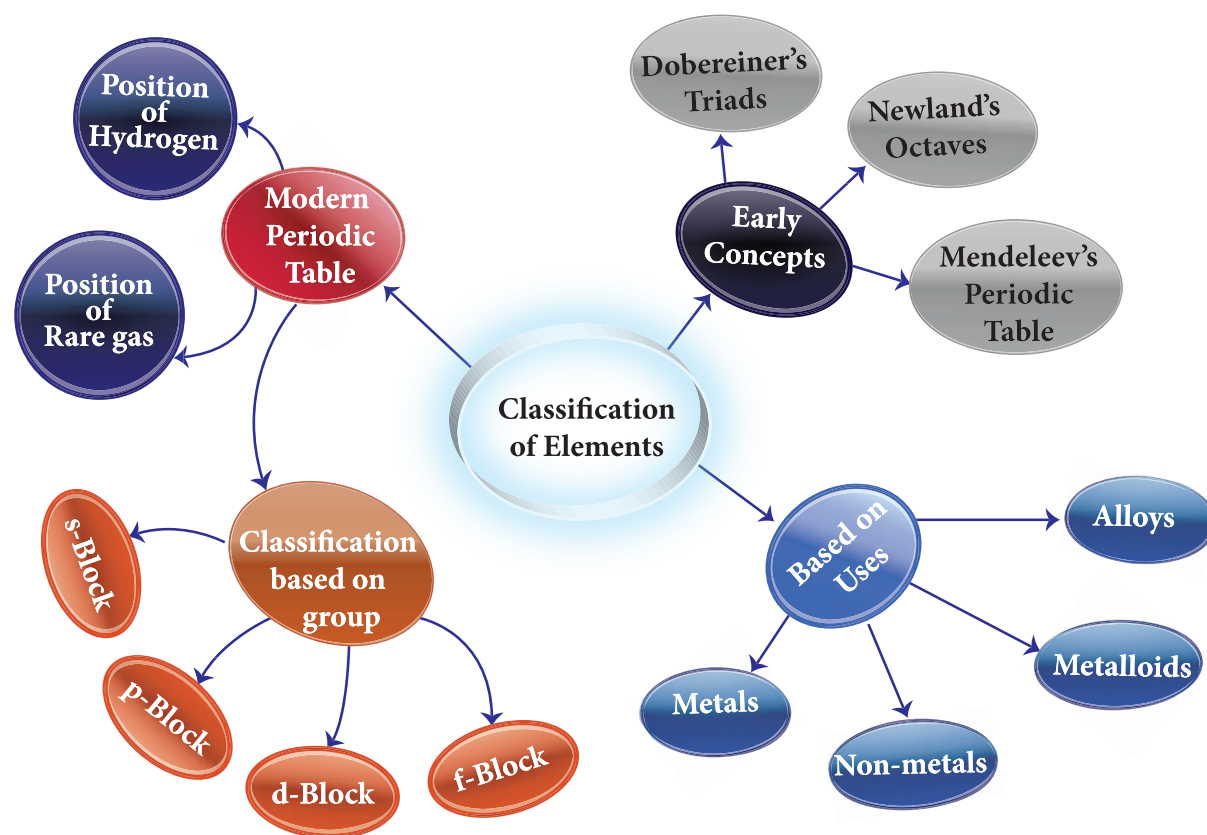
- State modern periodic law.
- What are groups and periods in the modern periodic table?
- What are the limitations of Mendeleev's periodic table?
- State any five features of modern periodic table.



REFERENCE BOOKS

- CONCISE Inorganic chemistry : 5th Edition by J.D. Lee
- Inorganic Chemistry by P.L.Soni
- The Periodic table: Its story and its significance: Eric R. Scerri

Concept Map



ICT CORNER

Periodic Classification

Steps

1. Type the URL link given below in the browser OR scan the QR code. You can also download the “**Royal society of chemistry**” mobile app from the given app URL.
2. Click the element from the table and explore the properties of the element you want to learn.
3. On the right top corner click option as shown to learn the uses and properties.
4. For every element we can understand the uses and the properties of elements.

