UNIT 4

Periodic classification of elements

Learning Objectives

BN8AZY

After studying this chapter, 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 periodic table.
- study about the position of Rare Gases (Noble gases) in the periodic table.
- distinguish between metals and non-metals.
- know about the metalloids and alloys.

Introduction

Think of a morning prayer in your school. Students stand in rows which are horizontal as well as vertical. Each class stands in a single line, height wise. Generally, height of students of class I is the shortest and that of class 12 is the tallest.

The vendor in a medical store could locate the medicines we seek in a flash of time with the use of a pattern they are arranged. We can easily identify the books in the library as quickly as possible.

There is a pattern in all these cases and this pattern makes the selection easy. (Pattern: regular arrangement)

We live in the world of substances with great diversity. The 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.

4.1. Early Concepts Of Classification Of Elements

4.1.1. DOBEREINER'S TRIADS

In 1817, Johann Wolfgang Dobereiner, a German chemist, suggested a method of grouping of 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 4.1 shows the law of triads proposed by Dobereiner:

Example: In the triad group (1), arithmetic mean of atomic masses of 1st and 3rd elements, (6.9 + 39.1)/2 = 23. So the atomic mass of Na (middle element) is 23.

Johann Wolfgang Dobereiner was a German chemist who is best known for his periodic law of triads of chemical elements. Dobereiner discovered furfural, used platinum as a catalyst and discovered a lighter, known as Dobereiner's lamp.

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 atomic mass and very high atomic mass.

Table 4.1 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

4.1.2 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 and 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.

DO YOU KNOW?

John Newlands (1837-1898) was a Scottish analytical chemist. He continued Dobereiner's work with triads and published his 'Law of Octaves' in 1865, which stated that 'any given element will exhibit analogous behaviour to the eighth element following it in the table.' Newlands arranged all the known elements, starting with hydrogen and ending with thorium, into seven groups of eight, which he linked to octaves of music. In Newlands' table, the elements were ordered by the atomic weights that were known at the time and were numbered sequentially to show their order. After Dmitri Mendeleev and Lothar Meyer, he received the prestigious Davy Medal in 1887.

Table 4.2 Newland's table of octaves (oct- eight)

NO.	NO.	NO.	NO.	NO.	NO.	NO.	NO.
H1	F8	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 & V45	Hg 52
BO 4	Al 11	Cr 19	Y 25	Ce & La33	U40	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
O7	S 14	Fe 21	Se 28	Ro&Ru 35	To 43	Au 49	Th 56

- 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.

4.1.3 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.

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.
- 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, and 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

Table 4.3 Mendeleev's Periodic Table

Group	I	II	III	IV	V	VI	VII	VIII
Oxide: Hydride:	R_2O RH	RO RH_4	R_2O_3 RH_4	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 18.988	
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 Second series	K 39.102 Cu 63.54	Ca 40.08 Zn 65.54	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 121.60	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 178.40 Pb 207.19	Ta 180.95 Bi 208.98	W 183.85		Os 190.2 Ir 192.2 Pt 195.05
7	Rn 222	Fr 223	Ra 226	Ac 227	Th 232	Pa 231	U 238	

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.

Table 4.4 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	$EsCl_4$	$GeCl_4$

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).
- 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

Activity 2

Name the class rooms in your school from the first element of the periodic table Hydrogen, Helium …. instead of numbering them. (*Example: Room no: 1- Hydrogen, Room no:2- Helium and so on*)

Dmitri Ivanovich Mendeleev (1834 - 1907) was a Russian chemist and inventor. He formulated the Periodic Law, and used it to correct the properties of some already discovered elements and also to predict the properties of eight elements yet to be discovered. Mendeleev also investigated the composition of petroleum and helped to establish the first oil refinery in Russia. He recognized the importance of petroleum as a source for petrochemicals. He is called as 'Father of Modern Periodic Table'.

4.2 MODERN PERIODIC TABLE

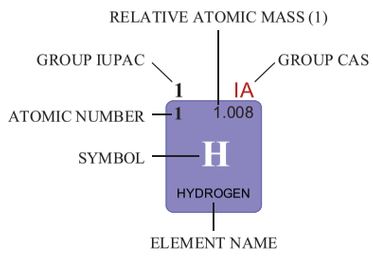
In 1913, the English Physicist Henry Moseley, through his X-ray diffraction experiments, proved that the properties of elements depend on the atomic number and not on the atomic mass. Consequently, the modern periodic table was prepared by arranging elements in the increasing order of their atomic number.

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

4.2.1 Modern Periodic Law

Atomic number of an element (Z) not only indicates the number of protons (positive charge) but also 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

PERIODIC TABLE OF THE ELEMENTS



Metal | Semimetal | Nonmetal
Alkali metal | Alkaline earth metal | Transition metals | Lanthanide | Actinide
Chalcogens element | Halogens element | Noble gas

STANDARD STATE (25 °C; 101 kPa)
Ne - gas | Fe - solid
Hg - liquid | Tc - synthetic

PERIOD / GROUP	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.008 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.94 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.81 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.085 Si SILICON	15 30.974 P PHOSPHORUS	16 32.06 S SULPHUR	17 35.45 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.38 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.971 Se SELENIUM	35 79.904 Br BROMINE	36 83.798 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.95 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (267) Rf RUTHERFORDIUM	105 (268) Db DUBNIUM	106 (271) Sg SEABORGIUM	107 (272) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (276) Mt MEITNERIUM	110 (281) Ds DARMSTADTIUM	111 (280) Rg ROENTGENIUM	112 (285) Cn COPERNICIUM	113 (285) Nh NIHONIUM	114 (287) Fl FLEROVIUM	115 (289) Mc MOSCOVIUM	116 (291) Lv LIVERMORIUM	117 (294) Ts TENNESSINE	118 (294) Og OGANESSON

LANTHANIDE

57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.05 Yb YTTERBIUM	71 174.97 Lu LUTETIUM

ACTINIDE

89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

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.

DO YOU KNOW?

Henry Gwyn Jeffreys Moseley (1887-1915) was an English physicist. He developed the chemical concept of atomic number. This concept was developed from his study of X-ray spectra.

Moseley's law advanced atomic physics, nuclear physics and quantum physics by providing the first experimental evidence in favour of Niels Bohr's theory, aside from the hydrogen atom spectrum which the Bohr theory was designed to reproduce. That theory refined Ernest Rutherford's and Antonius van den Broek's model, which proposed that the atom contains in its nucleus a number of positive nuclear charges that is equal to its atomic number in the periodic table. This remains the accepted model today. Moseley redefined the idea of atomic numbers from its previous status to help sorting the elements into an exact sequence of ascending atomic numbers that made the Periodic Table exact. This was later to be the basis of the Aufbau principle in atomic studies.

4.2.2 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 4.5 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

DO YOU KNOW?

The International Union of Pure and Applied Chemistry (IUPAC) is an international federation of Organizations that represents chemists from various countries. IUPAC is registered in Zürich, Switzerland, and the "IUPAC Secretariat", is in United States.

IUPAC
INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

Activity 3

List the elements (any five) which are used in our daily life by seeing the Modern Periodic table.

	Element	Use
1.	Flourine	toothpaste
2.	_____	_____
3.	_____	_____
4.	_____	_____
5.	_____	_____
6.	_____	_____

New elements named by IUPAC

The elements having atomic number 113 to 118 have been named by IUPAC as follows:

Nihonium (Nh) for Element 113. (Earlier it was Uut)

Moscovium (Mc) for Element 115. (Earlier it was Uup)

Tennessine (Ts) for Element 117. (Earlier it was Uus)

Oganesson (Og) for Element 118. (Earlier it was Uuo)

4.2.3 Classification of elements into blocks in Modern Periodic Table

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 manner. These subshells are designated as s, p, d, and f. The maximum number of electrons that can be accommodated in s, p, d, and f are 2, 6, 10 and 14 respectively.

Based on the arrangement of electrons in subshells, the elements of periodic table are classified into four blocks as shown in Table 4.6

(1) s-Block Elements

While arranging the electrons of elements of group 1 and 2, the last electron is added to s subshell. These elements are called s-block 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

Table 4.6 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
The maximum number of electrons in each sub shell	2	2	6	2	6	10	2	6	10	14
The maximum number of electrons in each shell	2	8		18			32			

dissolved in water. Hence, these elements are called alkaline earth metals.

(2) p-Block Elements

The last electron in these elements is filled in p subshells and hence these elements are called 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). 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

The elements of group 3 to 12 have their valence electrons in their outermost d subshells. These elements are called d block 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

Part of the group 3 elements have their valence electrons in inner f subshell. They are known as f block elements or inner transition elements. They are placed at the bottom of the periodic table. There are two series in f block elements. The elements that follow Lanthanum are called "Lanthanides" and that follow Actinium are called "Actinides".

Activity 4

Note down the atomic numbers of Li, Sc, Mg, Be, Al, B, C, Cl, N, O, F and Ne and find out the period that the elements are present.

Element	Atomic Number	Period Number
Li	3 (2,1)	2
Sc	21 (2,8, 8,3)	4

More to Know

- Most of the coloured salts are compounds of d block elements (transition elements).
- Most of the elements in d block accounts for variable oxidation states.
- Transition elements also show catalytic property.
- All the above properties of d block elements are due to the presence of transition ions.

4.2.4 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.

4.2.5 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.

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.

4.2.6. 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.

These gases are chemically inert or non-reactive in nature because they have stable electronic structures which are very difficult to change.

Though they are found rare, they have many uses.

1. Helium is used for filling weather balloon, as it has very low density.
2. Neon gas is used in discharge lamps for the orange column.
3. Argon gas is filled in electrical bulbs to prevent evaporation of the filament.
4. Radon is a radioactive gas.

More to Know

Hydrogen is the most abundant element in the universe, and makes up four-fifths of all ordinary matter. It is believed to be the fuel of the future, but it remains difficult to produce, transport and store. At extreme temperatures and pressures, like those at the core of a gas-giant planet, hydrogen can become metallic. (A gas giant is a large planet composed mostly of gases, such as hydrogen and helium, with a relatively small rocky core. The gas giants of our solar system are Jupiter, Saturn, Uranus and Neptune.)

Table 4.7 Electronic structure of Rare gases.

Element	Symbol	Atomic Number	Electronic Structure
Helium	He	2	2
Neon	Ne	10	2, 8
Argon	Ar	18	2, 8, 8
Krypton	Kr	36	2, 8, 18, 8
Xenon	Xe	54	2, 8, 18, 18, 8
Radon	Rn	86	2, 8, 8, 32, 18, 8

4.3 METALS, NON-METALS AND METALLOIDS

4.3.1 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. Sodium and Potassium

(ii) Alkaline earth metals e.g: Calcium and Magnesium

(iii) Transition Metals e.g: Iron and Nickel

(iv) Other Metals e.g: Aluminium and Tin

4.3.2. Non-metals

A non-metal is an element that does not have the characters of hard, shiny, malleable, suitable and ductile. In other words, a non-metal is an element that does not have the properties of metal. E.g. Oxygen, Nitrogen

4.3.3 Metalloids

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

4.4 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.

BNH72L

4.4.1 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

Table 4.8 Comparison of the physical properties of metals and non-metals

S. No	Properties	Metals	Non-metals
1.	Appearance	Have a lustre, known as metallic lustre. The surface is polishable.  Platinum Gold Silver	Have no lustre and I.k dull. Surface cannot be polished. (Exceptions: Graphite and iodine are lustrous).  Yellow - Sulphur,White - Phosphorous. Red - Bromine, Black-Carbon
2.	Physical state	In genral, they are hard crystaline solids.(Exception: Mercury is a liquid)	They exist as soft solids or gases. (Expections: Diamond is a hard solid and bromine is a liquid)
3.	Density	They have a high density. (Exceptions: Sodium and Potassium).	They have a low density.
4.	Melting and boiling points	Usually they have high melting and boling points. (Exceptions: Sodium and Potassium).	They have low melting and boiling points (Exceptions: diamond and graphite)
5.	Malleability and ductility	They are malleable and ductile.	Solid non-metals are brittle.
6.	Heat conductivity	They are good conductors.	They are bad conductors. (Exceptions: diamond)
7.	Electrical conductivity	They are good conductors	They are bad conductors. (Exception: Graphite)
8.	Sonority (phenornenon of producing a characteristic sound when a material is struck)	They are sonorous	They are non-sonorous. (Exception: Iodine crystals produce a soft metallic clink when they are shaken in a bottle)
9.	Alloy formation	Metals form alloys with each other and also with some non-metals	Non-metals usually do not form alloys. (Exception: B, C, Si and P from alloys with metals)

Table 4.9 Comparison of the chemical properties of metals and non-metals

S. No.	Chemical Property	Metals	Nonmetals
1.	Electro Positive / Electro Negative	Electro Positive. Metals lose electrons and form cation eg.) $Na \rightarrow Na^{+} + e^{-}$ $Al \rightarrow Al^{3+} + 3e^{-}$	Electro Negative. Nonmetals gain electrons and form anion $Cl + e^{-} \rightarrow Cl^{-}$ $O + 2e^{-} \rightarrow O^{2-}$
2.	Reaction with Oxygen	Metals burn with Oxygen to form metal oxides. Generally, these metal oxides are basic.	Nonmetals when heated with oxygen produce covalent oxides. Most of the non-metal oxides are acidic in nature.
3.	Reaction with water a) Cold Water	a) Metals like Sodium and Potassium react with cold water to liberate hydrogen gas.	a) Carbon reacts with water to form carbon monoxide and hydrogen
	b) Steam	b) Metals like Magnesium and Iron react with steam to form their respective oxides and hydrogen ii) Aluminium reacts slowly with steam to form aluminium hydroxide and hydrogen. Note : Copper, Nickel, Silver and Gold do not react with water.	Nonmetals are less reactive with steam
4.	Reaction with Acids	Metals such as Sodium, Magnesium, Aluminium react with dilute hydrochloric acid to give their respective salts.	Generally, nonmetals do not react with acids, but when heated with con. HNO_3 or con H_2SO_4, the respective oxides or oxy acids are formed.
5	Reaction with Halogens	Metals react with halogen to form ionic halides	Nonmetals react with halogens to form covalent halides
6	Oxidation/ Reduction	Metals get oxidized (lose electron) on reaction with nonmetals	Nonmetals get reduced (gain electron) on reaction with metals

Table 4.10 Composition and uses of alloys

S. No	Alloy	Composition	Uses
1	Brass	Cu & Zn (Copper and Zinc)	Decorative articles, taps etc.
2	Bronze	Cu & Sn (Copper and Tin)	Statues and medals
3	Solder	Pb & Sn (Lead and Tin)	Soldering electronic circuits
4	Stainless Steel	Fe, C, Cr and Ni (Iron, carbon , Chromium and Nickel)	Utensils, Surgical instruments
5	German Silver	Cu, Ni, Zn (Copper, Nickel and Zinc)	Artificial jewellery
6	Gun metal	Cu , Sn & Zn (Copper,Tin & Zinc)	Guns and frames of spectacles
7	Duralumin	Al, Mg, Cu & Mn (Aluminium, Magnesium, Copper & Manganese)	Bodies of aircraft
8	Magnalium	Al & Mg (Aluminium & Magnesium)	Kitchen wares
9	Steel	Fe & C (Iron and Carbon)	Ship construction etc

More to Know

Monel is an alloy of nickel (67%) and copper with small amounts of iron, manganese, carbon, and silicon. It is stronger than pure nickel and it is extremely resistant to corrosion even that caused by sea water. It is used in aircraft construction and skins of experimental rocket planes

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 column called 'groups' and seven horizontal rows called 'period'.
- The physical and chemical properties of elements depend not on the number of protons but on the number of electrons and their arrangements (electronic configuration) in atoms.
- 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.
- The maximum number of electrons that can be accommodated in s, p, d and f sub shells are 2, 6, 10 and 14 respectively.
- Lanthanides and actinides are kept at the bottom of the periodic table.
- Based on the arrangement of electrons in subshells, the elements of periodic table are classified into four blocks as s, p d and f.
- 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.
- Rare gases are chemically inactive because they have stable electronic structures which are very difficult to change.

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 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 electron is added to s subshell.
p block elements	Elements whose valence electron is filled in p subshells.
d block elements	Elements having their valence electrons in the d subshells.
Noble gases	The elements in group 18 of the periodic table are called as Noble gases or Rare gases.
Metals	Metals are hard, shiny, malleable (can be made as sheet), fusible and ductile (can be drawn into wire) with good electrical and thermal conductivity.

Non metals	A nonmetal is an element that does not have the characters of hardness, shiny, malleable, suitable and ductile.
Metalloids	Elements which have the properties of both metals and nonmetals are called as metalloids. (eg) Boron, Arsenic.
Alloys	Alloys are mixtures of two or more metals and are formed by mixing molten metals thoroughly.

TEXT BOOK EXERCISES

BNR349

I. Choose the correct answer

1. If Dobereiner is related with 'law of triads', then Newlands is related with
   a) Modern periodic law
   b) Hund's rule
   c) law of octaves
   d) Pauli's Exclusion principle

2. Modern periodic law states that the physical and chemical properties of elements are the periodic functions of their _____
   a) atomic numbers b) atomic masses
   c) similarities d) anomalies

3. Elements in the modern periodic table are arranged in ____ groups and ____ periods.
   a) 7, 18 b) 18,7 c) 17,8 d) 8, 17

4. The increasing order of the energy of subshells is
   a) s>p>d>f b) s<p<d<f
   c) s<p<f<d d) p<s<d<f

5. If the electronic configuration of an element is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$, then it will occupy _____ block of the periodic table
   a) s b) p c) d d) f

II. Fill in the blanks

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

III. Match the following

1.	Triads	Newlands
2.	Alkali metal	Calcium
3.	Law of octaves	Henry Moseley
4.	Alkaline earth metal	Sodium
5.	Modern Periodic Law	Dobereiner

IV. State whether True or False

1) Newlands' periodic table is based on atomic masses of elements and modern periodic table is based on atomic number of elements

2) Metals can gain electrons

3) Alloys bear the characteristics of both metals and nonmetals

4) 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

5) Group 17 elements are named as Halogens

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.

a) Statement is true and reason explains the statement.

b) Statement is false but the reason is correct.

VI. Answer the following

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

VII. Complete the following table

Element	Number of electrons	Sub shell electronic configuration
N	7	$1s^2$ $2s^2$ $2p^3$
F	9	1s 2s p
Na		
Cl		
Ar		

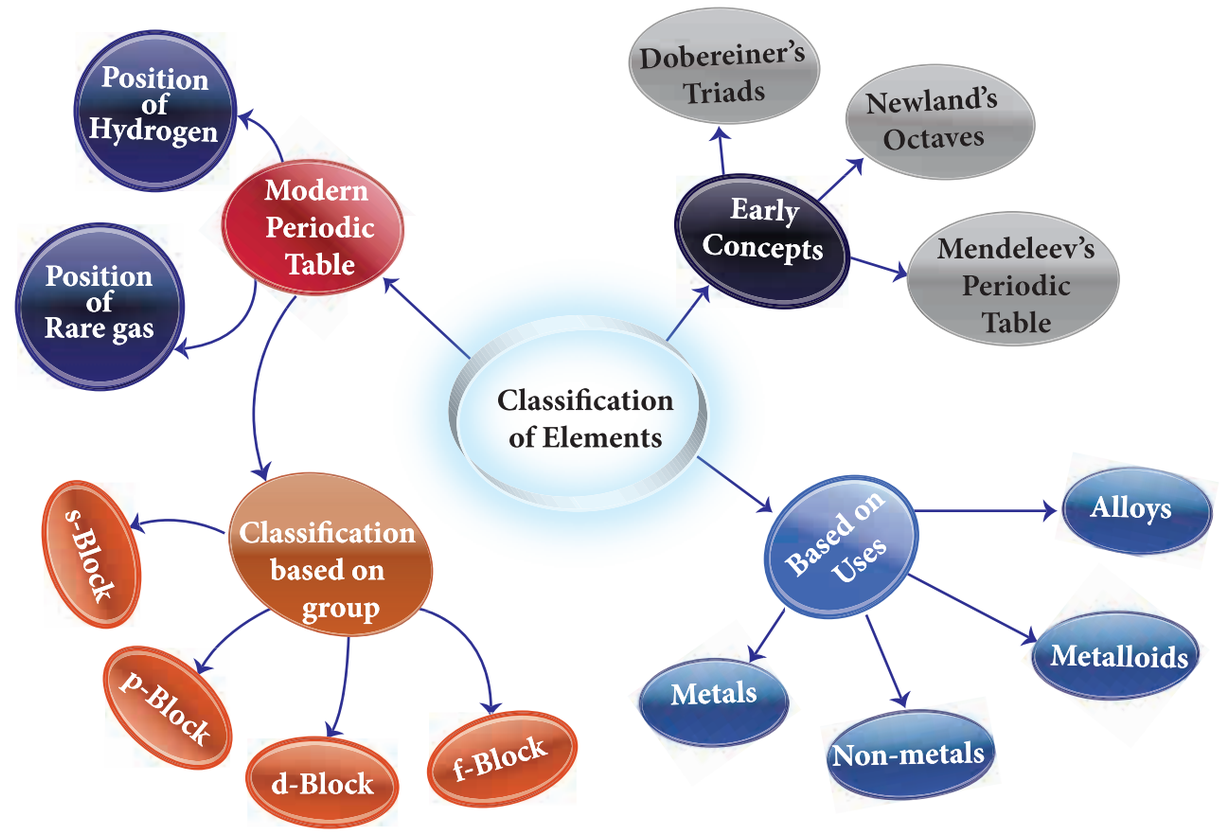
VIII. Arrange the jumbled letters to answer the following

1. We are a family of five and lies in 17th group of periodic table (7 letters)
2. I am being stored in kerosene and be cut by knife (6 letters)
3. I am the most corrosion resistant silvery white metal and lies in group 9 (7 letters)
4. I am being used as refrigerant in liquid form with atomic number 7 (8 letters)
5. I am in your blood as hemoglobin and without me no buildings are possible (4 letters)
6. I am the highly radioactive and newly designated element in the modern periodic table with atomic number 113 (8 letters)
7. I am used as a disinfectant for drinking water. (8 letters)
8. I am mixed with salt and used for thyroid health (6 letters)
9. I am the key part of biological molecules and have the valency of four. (5 letters)
10. I am the first in the noble gas group and used to fill balloons (6 letters)

S.No	Jumbled letters	Answer
1	L A O H S E N G	
2	S D I M U O	
3	R I D M U I I	
4	T I R N G O N E	
5	N R O I	
6	I H N M U I N O	
7	H C L E I R N O	
8	E N I D O I	
9	B A R C O N	
10	E L I H U M	

IX) Complete the following table referring the modern periodic table:

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



REFERENCE BOOKS

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

INTERNET RESOURCES

1. https://www.ptable.com/
2. https://iupac.org/what-we-do/periodic-table-of-elements/
3. www.rsc.org/periodic-table
4. https://sciencestruck.com/periodic-table-facts
5. https://ww.teachbeside.com/memorize-periodictable

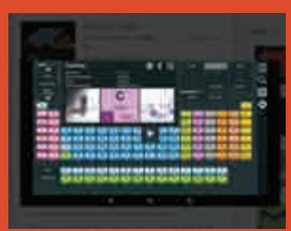
ICT CORNER

Periodic Classification

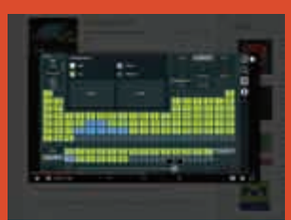
This activity enables to explore the properties of elements.

Steps

- 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.
- Click the element from the table and explore the properties of the element you want to learn.
- On the right top corner click option as shown to learn the uses and properties.
- For every element we can understand the uses and the properties of elements.



Step1



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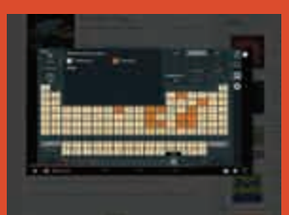
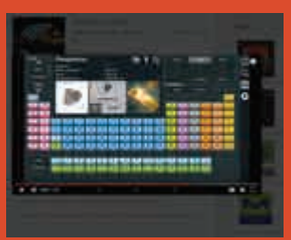


Step3



Step4

Browse in the link:

URL: https://play.google.com/store/apps/details?id=org.rsc.periodictable or Scan the QR Code.

*Pictures are indicative only

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