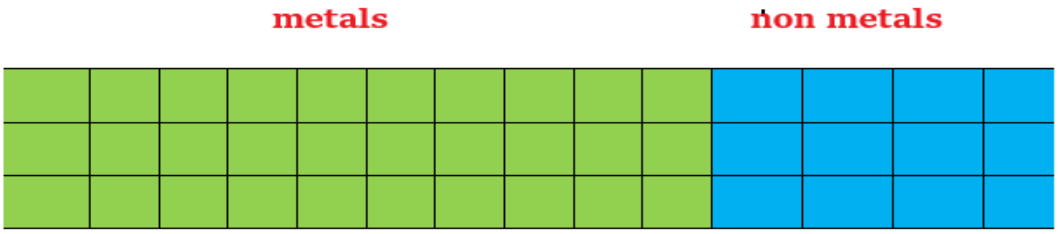
PERIODIC CLASSIFICATION OF ELEMENTS

Introduction

- At present, 118 elements are known to us. All these have different properties
- 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 and classify such a large number of elements with ease.

Early Attempts at the Classification of Elements

- The earliest attempt scientists made to classify the elements was done on the basis of properties of known elements resulted in grouping them as metals and non-metals.



- As our knowledge of elements and their properties increased, further classifications were tried out later. e.g.

Döbereiner's Triads

- In 1817, Johann Wolfgang Döbereiner, a German chemist, arranges the then elements with similar properties into groups.

H						He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	**P**	**S**	**Cl**	Ar
K	**Ca**	Ga	Ge	**As**	**Se**	**Br**	Kr
Rb	**Sr**	In	Sn	**Sb**	**Te**	**I**	Xe
Cs	**Ba**	Tl	Pb	Bi	Po	At	Rn

- Some groups having three elements each, he called these groups as 'triads.
- Döbereiner showed that when the three elements in a triad were written in the order of increasing atomic masses; the atomic mass of the middle element was roughly the average of the atomic masses of the other two elements.

- For example, take the triad consisting of lithium (Li), sodium (Na) and potassium (K) with the respective atomic masses 6.9, 23.0 and 39.0.
- The average of mass of lithium and potassium is 22.95 which is equal to the mass of the middle atom sodium (23.0)

Characteristics of Triads:

- Properties of elements in each triad were similar.
- Atomic mass of the middle element was roughly the average of the atomic masses of the other two elements.

Elements	atomic mass	average
lithium sodium potassium	6.9 23.0 39.0	$\frac{6.9+39.0}{2} = 22.95$
calcium strontium barium	40.1 87.6 137.3	$\frac{40.1 \quad 137.3}{2} = 88.65$
chlorine bromine iodine	35.5 79.9 126.9	$\frac{35.5+126.9}{2} = 81.2$

Limitations of Dobereiner classification

- Dobereiner could identify only three triads i.e. total of nine elements.
- He was not able to prepare triads of all the known elements. Hence, this system of classification into triads was not found to be useful

Newlands' Law of Octaves

- To overcome the limitations of Dobereinier classification, in 1866, John Newlands, an English scientist, arranged the then known elements in the order of increasing atomic masses.
- He started with the element having the lowest atomic mass (hydrogen) and ended at thorium which was the 56th element.
- He found that every eighth element had properties similar to that of the first. He compared this to the octaves found in music. Therefore, he called it the 'Law of Octaves'.
- To Newlands, H to F and F to Cl are octaves of eight elements, the eighth element repeating the properties of the first.

Newlands (1865)

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
Be 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	Tl 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	Te 43	Au 49	Th 56

- In Newlands' Octaves, the properties of lithium and sodium were found to be the same.
- Sodium is the eighth element after lithium. Similarly, beryllium and magnesium resemble each other.

Limitations of new land classification

- Law of Octaves was applicable only up to calcium, as after calcium every eighth element did not possess properties similar to that of the first.
- It was assumed by Newlands that only 56 elements existed in nature and no more elements would be discovered in the future. But, later on, several new elements were discovered.
- In order to fit elements into his Table, Newlands adjusted two elements in the same slot, but also put some unlike elements under the same note.
- E.g. cobalt and nickel are in the same slot and these are placed in the same column as fluorine, but chlorine and bromine which have very different properties than these elements and Iron which resembles cobalt and nickel in properties has been placed far away from these elements.
- With the discovery of noble gases, the Law of Octaves became irrelevant.
- Newlands' Law of Octaves worked well with lighter elements only

Mendeleev's law of classification of elements:

The main credit for classifying elements goes to Dmitri Ivanovich Mendeleev.

The periodic table

Dmitri Mendeleev (1869)

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 Co Ni 55.85 58.93 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 Rh Pd 101.07 102.91 106.4
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 Ir Pt 190.2 192.2 195.09

- Mendeleev was a Russian chemist; started his work on 63 elements that were known. He arranged elements on the basis of their-
- Fundamental property- the atomic mass.
- Similarity of their chemical properties.
- He observed that most of the elements got a place in a Periodic Table and were arranged in the order of their increasing atomic masses.

- Among chemical properties, Mendeleev concentrated 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. He observed that there occurs a periodic recurrence of elements with similar physical and chemical properties.
- On this basis, Mendeleev formulated a Periodic Law, which states that 'the properties of elements are the periodic function of their atomic masses.

Features of Mendeleev's periodic table

- Mendeleev arranged the elements in horizontal rows (known as periods) in the increasing order of their atomic masses.
- The elements are arranged in vertical column (known as groups) according to resemblances in their properties
- The formulae of the hydrides and oxides formed by an element were treated as one of the basic properties of an element for its classification
- The periodic table consists of 8 groups and 6 periods.
- He left gaps for the undiscovered as only 63 elements were known at that time

Achievements of Mendeleev's Periodic Table

- Mendeleev's predictions that led chemists not only to accept his Periodic Table but also recognize him as the originator of the concept on which it is based. Some of the main achievements of Mendeleev's periodic table are:
- Mendeleev arranged the elements on the basis of their similar properties.
- Mendeleev left some gaps in his Periodic Table. He believed the existence of some undiscovered elements at that time.
- Mendeleev named undiscovered elements by prefixing a Sanskrit numeral-Eka (one) to the name of preceding element in the same group having similar properties. For instance:
- Scandium, gallium and germanium, discovered later, have properties similar to Eka–boron, Eka–aluminum and Eka–silicon, respectively
- Mendeleev believed that Noble gases like helium (He), neon (Ne) and argon (Ar) are very inert and present in extremely low concentrations in our atmosphere, when these gases were discovered, they could be placed in a new group without disturbing the existing order.

Limitations of Mendeleev's Classification

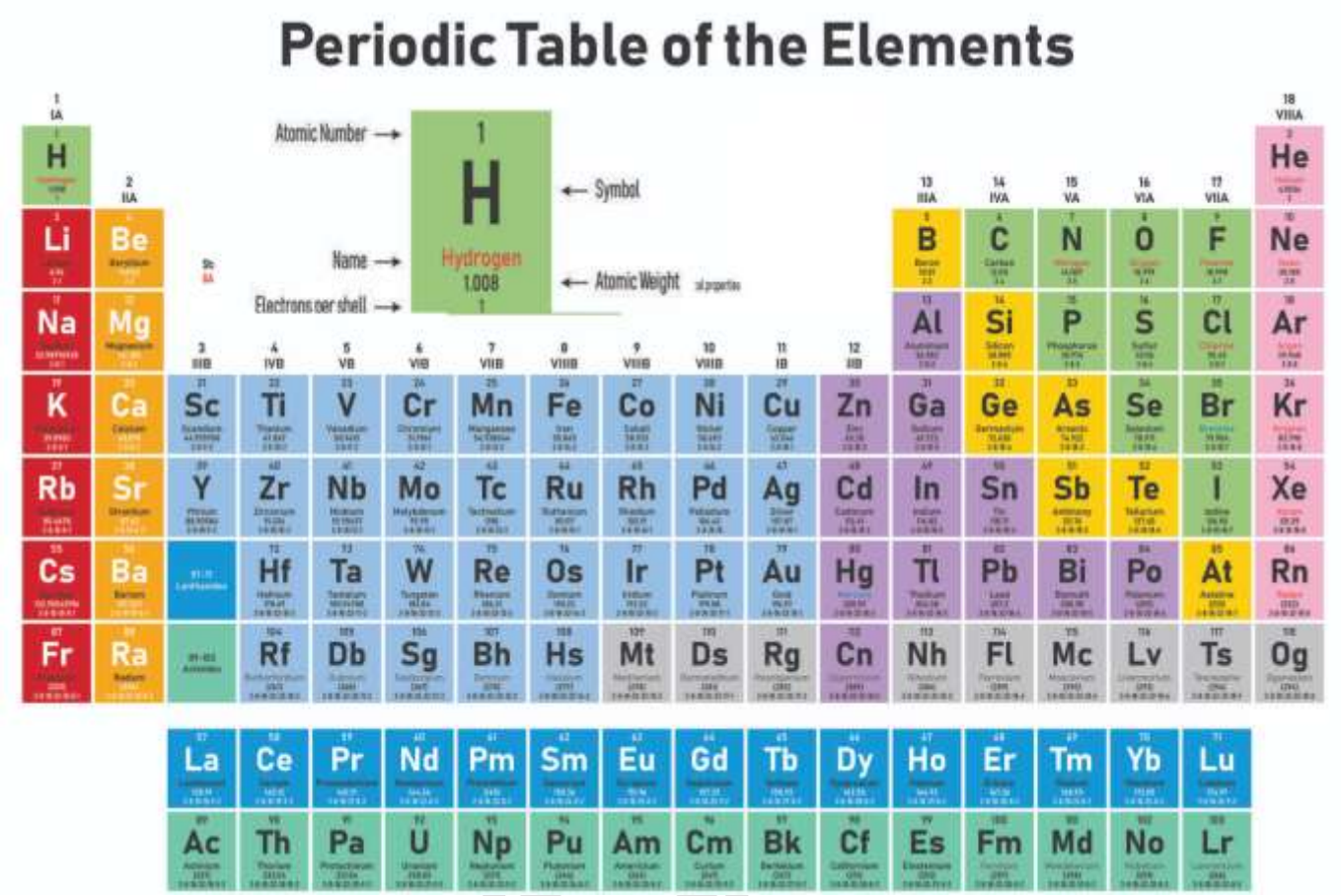
1. Mendeleev was unable to assign a correct position to hydrogen in his Table because hydrogen has same chemical properties like alkali metals and halogens as-
2. Electronic configuration of hydrogen resembles that of alkali metals. Hydrogen combines with halogens, oxygen and sulphur to form compounds having similar formulae like alkali metals as shown.

Compounds of H	Compounds of Na
HCl	NaCl
H2O	Na2O
H2S	Na2S

3. Just like halogens, hydrogen also exists as diatomic molecules and it combines with metals and non-metals to form covalent compounds.
4. Mendeleev believed that the properties of elements are the periodic function of their atomic masses'. Isotopes of an element have similar chemical properties but different atomic masses.
5. Furthermore atomic masses do not increase in a regular manner in going from one element to the next. So, it was not possible to predict how many elements could be discovered between two elements.

The Modern Periodic Table

- In 1913, Henry Moseley showed that the atomic number (symbolized as Z) of an element is a more fundamental property than its atomic mass. The atomic number gives us the number of protons in the nucleus of an atom and this number (number of protons) increases by one in going from one element to the next.
- Elements, when arranged in order of increasing atomic number, lead us to the classification known as the Modern Periodic Table



Features of Modern Periodic Table

- There are 18 vertical columns in the periodic table. Each column is called a group. All elements in a group have similar chemical and physical properties because they have the same number of outer electrons.
- In periodic table elements are arranged in a series of rows known as periods. There are 7 periods. Elements of the same period have the same number of electron shells.
- Light metals these are elements of periodic table of group 1 and 2
- Heavy metals or Transition metals - These are elements of periodic table of group 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12.
- Non-Metals these are elements of periodic table of group 13, 14, 15, 16 and 17.
- Zero group these are elements of periodic table of group 18

Cause of Periodicity – Definition

- The modern periodic table is based on the electronic configuration of the elements.
- The properties of an element are determined largely by the electrons in its outermost or valence shell.
- Valence electrons interact with other atoms and take part in all chemical reactions, while inner shell electrons have little influence on the properties of elements.
- When elements are placed in the order of their increasing atomic number, the elements having the same number of valence shell electrons is repeated in such a way, so as to fall under the same group.
- Since, the electronic configuration of the valence shell electrons is same they show similar properties.

Modern Periodic Law

- Modern Periodic Law can be stated as follows: 'Properties of elements are a periodic function of their atomic number E.g.
- Valency: The valency of an element is determined by the number of valence electrons present in the outermost shell of its atom. All the elements of a group have the same number of valence electrons. Therefore, they all have the same valency.
- Atomic size: The term atomic size refers to the radius of an atom which is defined as the distance between the Centre of the nucleus and the outermost shell of an isolated atom E.g. The atomic radius of hydrogen atom is 37 pm (picometre, 1 pm = 10–12m).
- Down the group -the atomic size increases; this is because new shells are being added as we go down the group.
- Along the period – Atomic size decreases because effective nuclear charge increases by one unit and it pulls valence electrons or the electron cloud closer to the nucleus hence decreases the atomic size.