2. Some elements showed properties of both-metals and non-metals and they could not be placed in any of the two classes.

After this, scientists made attempts to recognize some pattern or regularity in variation of properties of elements and to classify them accordingly. Now we shall learn about some of them.

4.1.1 Dobereiner's triads

In 1829, **Dobereiner**, a German scientist made some groups of three elements each and called them **triads**. All three elements of a triad were similar in their properties. He observed that the atomic mass* of the middle element of a triad was nearly equal to the arithmetic mean of atomic masses of other two elements. Also, same was the case with their other properties.

Element	**Atomic mass**
Lithium, Li	7
Sodium, Na	23
Potassium, K	39

Let us take the example of three elements lithium, sodium and potassium. They form a Dobereiner's triad.

Mean of the atomic masses of the first (Li) and the third (K) elements: $\frac{7+39}{2} = 23\text{ u}$

The atomic mass of the middle element, sodium, Na is equal to 23 u. Two more examples of Dobereneir's triads are given below.

Element	**Atomic mass**
Calcium, Ca	40
Strontium, Sr	88
Barium, Ba	137

Element	**Atomic mass**
Chlorine, Cl	35.5
Bromine, Br	80
Iodine, I	127

Mean of the atomic masses of the first and third elements = $\frac{40+137}{2}$ = 88.5 u

Mean of the first atomic masses of the and third elements = $\frac{35.5+127}{2}$ = 81.5 u

Actual atomic mass of the second element = 88 u

Actual atomic mass of the second element = 80 u

Dobereneir's idea of classification of elements into triads did not receive wide acceptance as he could arrange only a few elements in this manner.

4.1.2 Newland's law of Octaves

In 1864 **John Alexander Newland**, an English chemist noticed that "when elements are arranged in the increasing order of their atomic masses* every eighth element had properties similar to the first element." Newland called it the **Law of Octaves.** It was due to its similarity with musical notes where, in every octave, after seven different notes the eighth note is repetition of the first one as shown below.

1	2	3	4	5	6	7	8
lk	j	xk	e	i	/k	uh	lk

*Then known as atomic weight

PERIODIC TABLE (*Modified form of Mendleeff's Table*)

PERIODS	Group :	I		II		III		IV		V		VI		VII		VII	Zero
	Oxide:	R_2O		RO		R_2O_3		R_2O_5		R_2O_5		RO_3		R_2O_7		Ro_4	Noble gases
	Hydride:	RH		RH_2		RH_3		RH_4		RH_3		RH_2		RH		Transition Traids	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B		
1		H 1 (At. No.) 1.008(At.Wt.)															He 2 4.0026
2		Li 3 6.939		Be 4 9.012		B 5 10.811		C 6 12.011		N7 14.007		O 8 15.999		F 9 18.998			Ne 10 20.183
3		Na 11 22.99		Mg 12 24.312		Al 13 26.981		Si 14 28.086		P 15 30.974		S 16 32.06		Cl 17 35.453			Ar 18 39.948
4	**First series**	K 19 39.102		Ca 20 40.08			Sc 21 44.96		Ti 22 47.90		V 23 50.94		Cr 24 51.99		Mn 25 54.939	Fe 26 Co 27 Ni 28 55.85 58.93 58.71	
	second series		Cu 29 63.54		Zn 30 65.37	Ga 31 69.72		Ge 32 72.59		As 33 74.92		Se 34 78.96		Br 35 79.909			Kr 36 83.80
5	**First series**	Rb 37 85.47		Sr 38 87.62			Y 39 88.905		Zr 40 91.22		Nb 41 92.906		Mo 42 95. 94		Tc 43 (99)	Ru 44 Rh 45 Pd 46 101.07 102.91 106.4	
	second series		Ag 47 107.87		Cd 48 112.40	In 49 114.82		Sn 50 118.69		Sb 51 121.75		Te 52 127.60		I 53 124.9014			Xe 54 131.30
6	**First series**	Cs 55 132.90		Ba 56 137.34			*Rare Earths 57-71		Hf 72 178.49		Ta 73 180.948		W 74 183.85		Re 75 186.2	O s 76 Ir 77 Pt 78 190.2 192.2 195.09	
	second series		Au 79 196.97		Hg 80 200.59	Tl 81 204.37		Pb 82 207.19		Bi 83 208.98		Po 84 (210)		At 85 (210)			Rn 86 (222)
7		Fr 87 (223)		Ra 88 (226)		† Actinide Elements 89-103			Ku 104		Ha 105						

*** Lanthaandie Elements** *(Rare Earth Series)*

La 57	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
138.91	140.12	140.91	144.24	(147)	150.35	151.96	157.25	158.92	162.50	164.93	167.26	168.93	173.04	174.97

† Actinide Series

Ac 89	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103
(227)	232.04	(231)	238.3	(237)	(244)	(243)	(245)	(247)	(249)	(254)	(253)	(256)	(253)	(257)

Fig. 4.1 Mendeleev's periodic table

4.1.3b Main features of Mendeleev's periodic table

Look at the Mendeleev's periodic table shown in fig.4.2 carefully. What do you observe? Here, elements are arranged in tabular form in rows and columns. Now let us learn more about these rows and columns and the elements present in them.

1. The horizontal rows present in the periodic table are called **periods**. You can see that there are seven periods in the periodic table. These are numbered from 1 to 7 (Arabic numerals).
2. Properties of elements in a particular period show regular gradation (i.e. increase or decrease) from left to right.
3. The vertical columns present in it are called **groups**. You must have noticed that these are nine in number and are numbered from I to VIII and Zero (Roman numerals).
4. Groups I to VII are subdivided into A and B subgroups. Groups Zero and VIII don't have any subgroups.
5. All the elements in a particular group are chemically similar in nature. They show regular gradation in their physical properties and chemical reactivities.

After learning about the main features we shall now learn about the main merits of Mendeleev's periodic table.

4.1.3c Merits of Mendeleev's periodic classification

1. **Classification of all elements**

   Mendeleev's was the first classification which successfully included all the elements.
2. **Prediction of new elements**

Mendeleev's periodic table had some blank spaces in it. These vacant spaces were for elements that were yet to be discovered. For example, he proposed the existence of an

Can you explain this trend? You have learnt in the beginning of this section that in a period there is a gradual increase in the nuclear charge. Since valence electrons are added in the same shell, they are more and more strongly attracted towards nucleus. This gradually decreases atomic radii.

4.3.2b Variation of atomic radii in a group

What happens to atomic radii in a group? *Atomic radii increase in a group from top to bottom*. This can be seen from the data of atomic radii in picometers given for groups 1 and 17 elements below.

Element	Atomic radius	Element	Atomic radius
Li	155	F	72
Na	190	Cl	99
K	235	Br	114
Rb	248	I	133

As we go down a group the number of shells increases and valence electrons are present in higher shell and the distance of valence electrons from nucleus increases. For example, in lithium the valence electron is present in 2nd shell while in sodium it is present in 3rd shell. Also, the number of filled shells between valence electrons and nucleus increases. Thus in group 1 Li (2,1) has one filled shell between its nucleus and valence electron while Na (2,8,1) has two filled shells between them. Both the factors decrease the force of attraction between nucleus and valence electron. Therefore, atomic size increases on moving down a group.

4.3.3 Ionic radii

Ionic radius *is the radius of an ion*. On converting into an ion the size of a neutral atom changes. Anion is bigger than the neutral atom. This is because addition of one or more electrons increases repulsions among electrons and they move away from each other. On the other hand a cation is smaller than the neutral atom. When one or more electrons are removed, the repulsive force between the remaining electrons decreases and they come a little closer.

4.3.3a Variation of ionic radii in periods and groups

Ionic radii show variations similar to those of atomic radii. Thus, *ionic radii increase in a group*. You can see such increases in groups 1 and 16 elements from the data given below.

Group 1		Group 16	
Element	**Electron radius**	**Element**	**Ionic radius**
Li^+	60	O^{2-}	140
Na^+	95	S^{2-}	184
K^+	133	Se^{2-}	198
Rb^+	148	Te^{2-}	221

Ionic radii decrease in a period . It can be seen from the data of ionic radii in picometer for 2nd period elements given below.

Element	Li^+	Be^{2+}	B	C	N^{3-}	O^{2-}	F^-
Ionic radii	60	31	-	-	171	140	136