CHAPTER 5

PERIODIC CLASSIFICATION

Acknowledgment

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Contents

Earliest classification

The earliest attempt to classify the elements were as metals and non-metals.

Need for classification

When elements are classified such that they have the same properties

- Study of large number of elements is reduced to study of few groups of elements.
- It makes the study systematic.

Dobereiner's Classification

Dobereiner, a German scientist made the first attempt to classify elements on the basis of atomic mass.

Dobereiner Law of Triads

"When elements are arranged in the order of increasing atomic masses in groups of three elements, the atomic mass of the middle element of the triad is equal to the average atomic mass of the other two elements."

Dobereiner Law of Triads

Take the triads consisting of lithium (Li), sodium (Na) and potassium (K) with atomic masses 6.9, 23.0 and 39.0. Average atomic mass of Li and K is 6.9+39.0=45.9/2=22.95. The atomic mass of Na is 23.0

Dobereiner Law of Triads

Atomic Mass (1850)			Atomic Number		
Li	7		Li	3	
Na	23	$\frac{7+39}{2} = 23$	Na	11	$\frac{3+19}{2} = 11$
K	39		K	19	
Ca	40		Ca	20	
Sr	87	$\frac{40+137}{2} = 88.5$	Sr	38	$\frac{20+56}{2} = 38$
Ba	137		Ba	56	
P	31		P	15	
As	75	$\frac{31+122}{2} = 76.5$	As	33	$\frac{15+51}{2} = 33$
Sb	122		Sb	51	
S	32		S	16	
Se	78	$\frac{32+128}{2} = 80$	Se	34	$\frac{16+52}{2} = 34$
Te	128		Te	52	
Cl	35.5		Cl	17	
Br	80	$\frac{35.5+127}{2} = 81.25$	Br	35	$\frac{17+53}{2} = 35$
I	127		I	53	

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

Limitations of Dobereiner Law of Triads

a) All the then known elements could not be arranged in the form of triads.

b) The law failed for very low mass or for very high mass elements. In case of F, Cl, Br, the atomic mass of Cl is not an arithmetic mean of atomic masses of F and Br.

c) As the techniques improved for measuring atomic masses accurately, the law was unable to remain strictly valid.

Newland's Classification

Newland, an English chemist arranged the elements in the increasing order of atomic mass.

Newlands Law of octaves

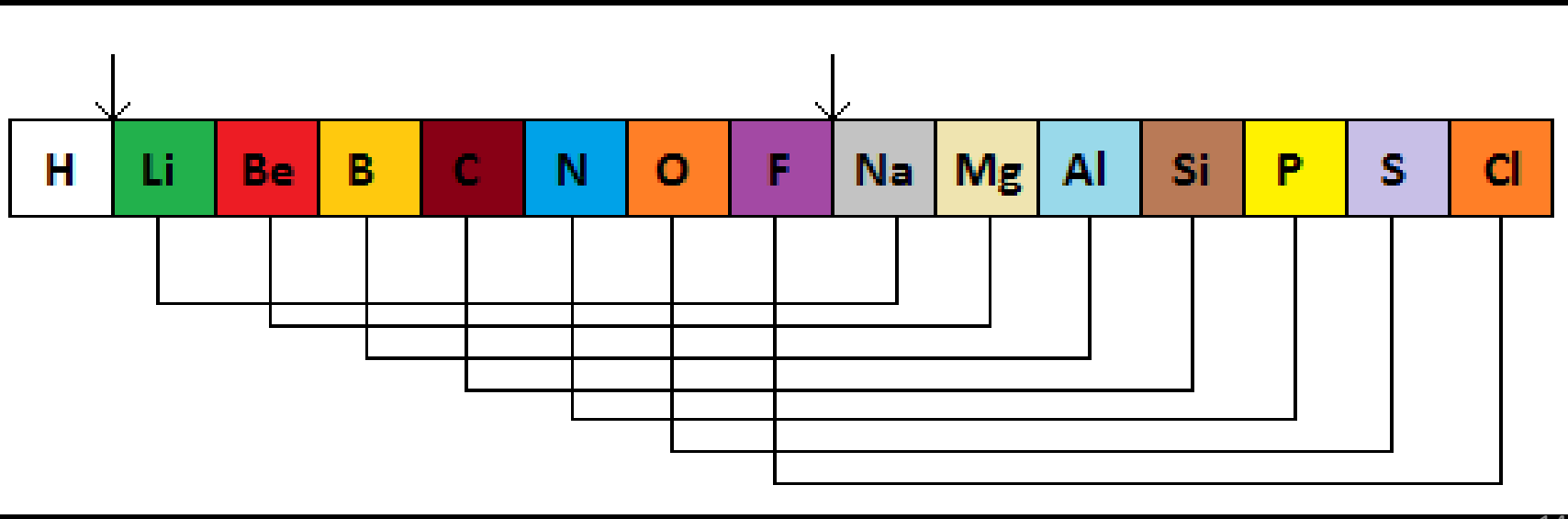
"When elements are arranged in the order of increasing atomic mass, the properties of the eighth element (starting from any given element) are a repetition of the properties of the first element".

Newlands Law of octaves

Do 1	Re 2	Mi 3	Fa 4	Sol 5	La 6	Si 7
H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe
Co, Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce, La	Zr	Di, Mo	Ro, Ru
Pd	Ag	Cd	U	Sn	Sb	I
Te	Cs	Ba, V	Ta	W	Nb	Au
Pt, Ir	Os	Hg	Tl	Pb	Bi	Th

Newlands Law of octaves

In the series of eight musical notes, after a certain interval the note will repeat itself.



Limitations of Newlands Law of octaves

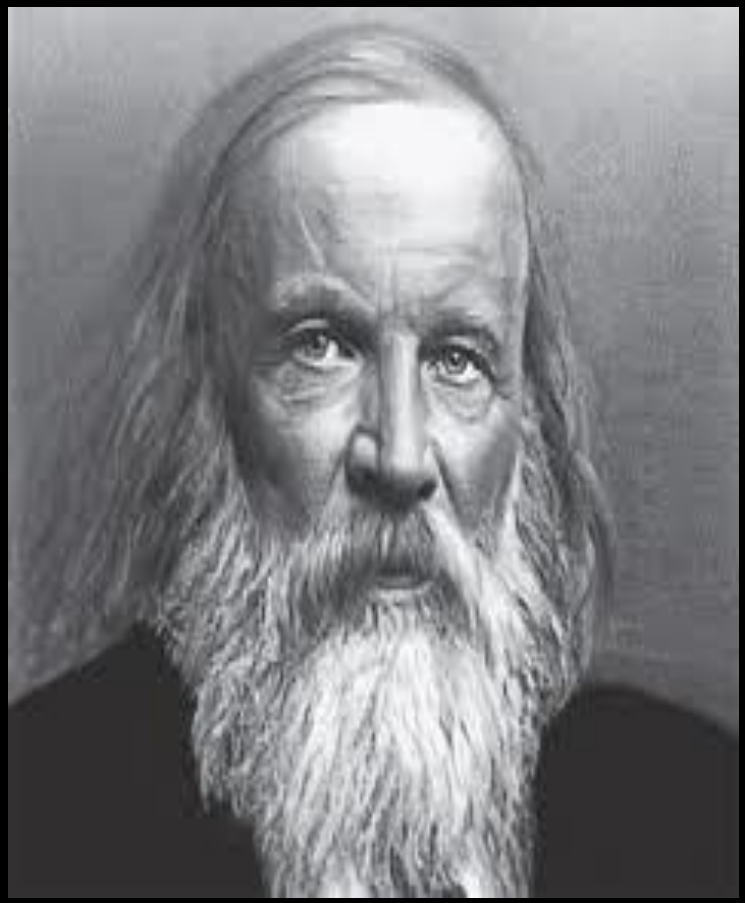
a) Newland law of octaves was applicable only upto calcium as after calcium every eighth element did not possess properties similar to that of the first.

b) Newland assumed that only 56 elements existed in nature. Several new elements were discovered, whose properties did not fit into the Law of Octaves.

c) 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.

Mendeleev's classification

Mendeleev, a Russian chemist classified elements by keeping them in groups and columns.



Why did Mendeleev select hydrogen and oxygen as standard?

Mendeleev selected hydrogen and oxygen as they are very reactive and formed compounds with most elements.

Basic property for Mendeleev's classification

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.

Mendeleev Periodic Law

"The properties of elements are periodic functions of their atomic mass".

Characteristics of Mendeleev PT

1) Mendeleev's periodic table consists of 7 periods (horizontal) and 9 groups (vertical).
2) Elements are arranged in the increasing order of their atomic weights.
3) The elements that have similar property were placed in vertical columns.

Advantages of Mendeleev PT

1) Mendeleev left vacant spaces in the table for the elements that were to be discovered.
2) He was able to predict the atomic mass and properties of elements even before their discovery.
3) His periodic table helped to discover new elements like germanium.

Mendeleev PT

Tabelle II.

Reihen	Gruppe I. — R^1O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H = 1							
2	Li = 7	Be = 9,4	B = 11	C = 12	N = 14	O = 16	F = 19	
3	Na = 23	Mg = 24	Al = 27,3	Si = 28	P = 31	S = 32	Cl = 35,5	
4	K = 39	Ca = 40	— = 44	Ti = 48	V = 51	Cr = 52	Mn = 55	Fe = 56, Co = 59, Ni = 59, Cu = 63.
5	(Cu = 63)	Zn = 65	— = 68	— = 72	As = 75	Se = 78	Br = 80	
6	Rb = 85	Sr = 87	?Yt = 88	Zr = 90	Nb = 94	Mo = 96	— = 100	Ru = 104, Rh = 104, Pd = 106, Ag = 108.
7	(Ag = 108)	Cd = 112	In = 113	Sn = 118	Sb = 122	Te = 125	J = 127	
8	Cs = 133	Ba = 137	?Di = 138	?Ce = 140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er = 178	?La = 180	Ta = 182	W = 184	—	Os = 195, Ir = 197, Pt = 198, Au = 199.
11	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	—	—	
12	—	—	—	Th = 231	—	U = 240	—	— — — —

Give example to show that Mendeleev had to place slightly greater atomic mass before an element with slightly lower atomic mass.

1) Cobalt (atomic mass 58.9) was placed before nickel (atomic mass 58.7)
2) Aluminium (atomic mass 29.98) was place before silicon (atomic mass 28.09)
3) V (atomic mass 50.94) was place before chromium (atomic mass 50.20)
4) Te (atomic mass 127.60) was placed before iodine (atomic mass 126.90)

Why was the discovery of Nobel gases like helium, neon, argon delayed?

Nobel gases like helium, neon and argon were discovered late because they are very inert and present in extremely low concentrations in our atmosphere.

Achievements of Mendeleev's periodic table

i) Some gaps were left for the undiscovered elements like gallium (Ga), Scandium (Sc) and Germanium (Ge).
(ii) Predict properties of elements on the basis of their positions in the periodic table.
(iii) Accommodate noble gases when they were discovered without disturbing the original arrangement.

Limitations of Mendeleev's periodic table

a) Position of hydrogen:

The position of hydrogen in the table is not certain because it can be placed in group IA as well as in group VIIA as it resembles both with alkali metals of IA group and halogens of VIIA group.

Limitations of Mendeleev's periodic table

b) Anomalous pair of elements:
Certain elements of highest atomic mass precede those with lower atomic mass.

Limitations of Mendeleev's periodic table

c) Dissimilar elements placed together: elements with dissimilar properties were placed in same group as sub-group A and sub-group B. For example, alkali metal like Li, Na, K etc., of IA group have little resemblance with coinage metals like Cu, Ag, Au of IB group.

Limitations of Mendeleev's periodic table

d) Some similar elements separated:
some similar elements like 'copper and mercury' and 'silicon and thalium' are placed in different groups of the periodic table.
e) Position of isotopes: isotopes of elements are placed in the same position in the table.

(Activity 5.1) Looking at its resemblance to alkali metals and the halogen family, try to assign hydrogen a correct position in Mendeléev's Periodic Table. To which group and period should hydrogen be assigned?

No fixed position can be given to hydrogen in the Mendeleev's periodic table.

Isotope of an element

The meaning of isotope is iso-same, tope-place.

Atoms having different atomic masses with the same atomic number. They are given the same place in the periodic table.

(Activity 5.2) Consider the isotopes of chlorine, Cl-35 and Cl-37. Would you place them in different slots because their atomic masses are different? Or would you place them in the same position because their chemical properties are the same?

No, the more fundamental base of classification is atomic number and not atomic mass. Yes, both the isotopes are placed in same position because they have same chemical properties and same atomic number.

Criteria used by Mendeléev in creating his Periodic Table

The criteria used by Mendeléev were:
(i) Physical and chemical properties of the elements.
(ii) Atomic masses in increasing order.

Why were noble gases are placed in a separate group?

Noble gases are also called inert gases because they have a complete octet and are very stable. They do not react with other elements due to their stability. Since they all are unreactive, have complete octet and similar behaviour so they are placed in a separate group.

Modern Periodic table

Modern periodic law

"The properties of elements are a periodic function of their atomic number".

Characteristics of Modern Periodic Table

1) Elements are arranged according to increasing atomic numbers.
2) Elements having similar properties are kept in the same group.
3) There is a inter relation between electronic configuration and atomic number.

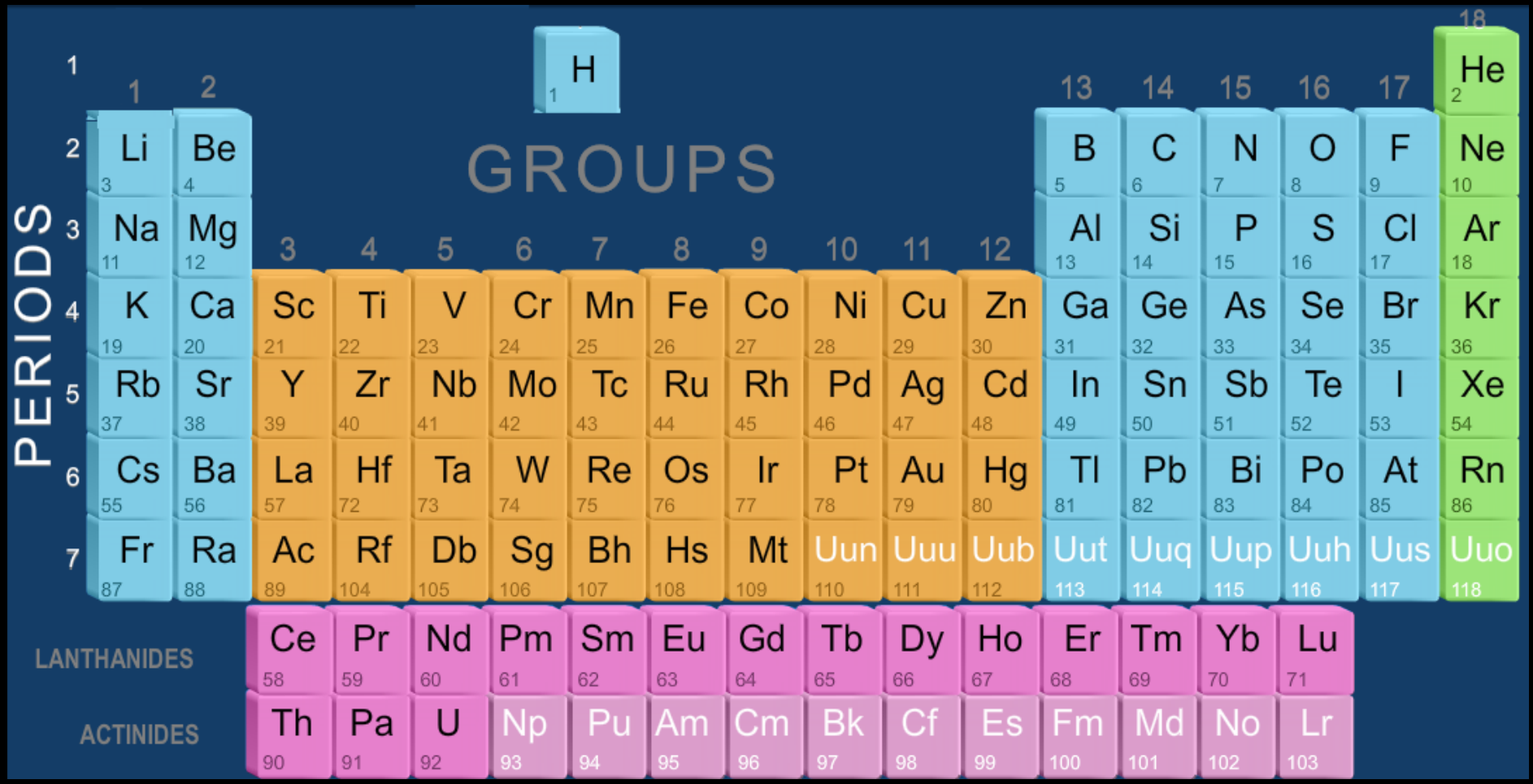
Characteristics of Modern Periodic Table

4) The elements are arranged in 7 horizontal rows called periods and 18 vertical columns called groups.

Difference between Mendeleev & Modern

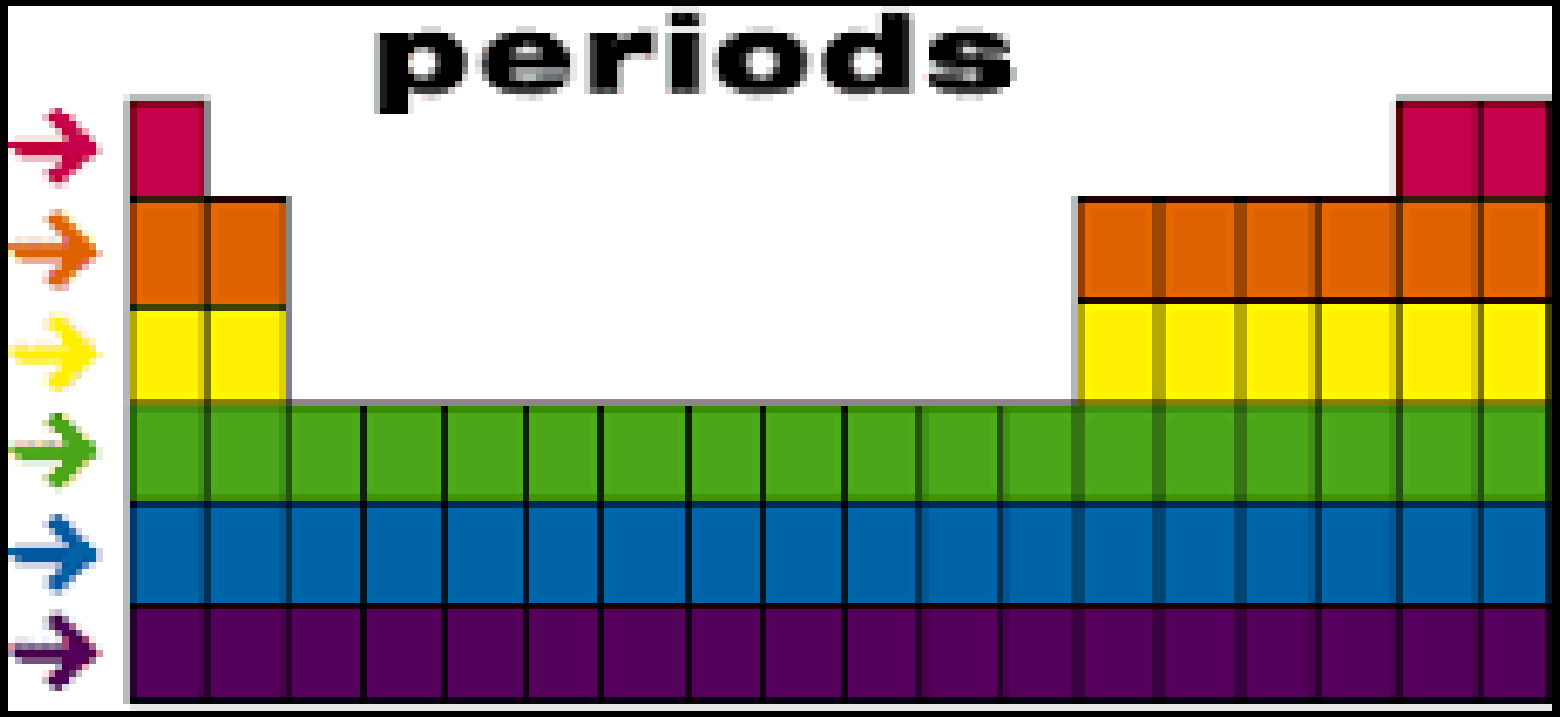
Mendeleev's	Modern
Elements are arranged in the order of increasing atomic masses.	Elements are arranged in the order of increasing atomic numbers.
There are 8 groups	There are 18 groups

Modern Periodic Table



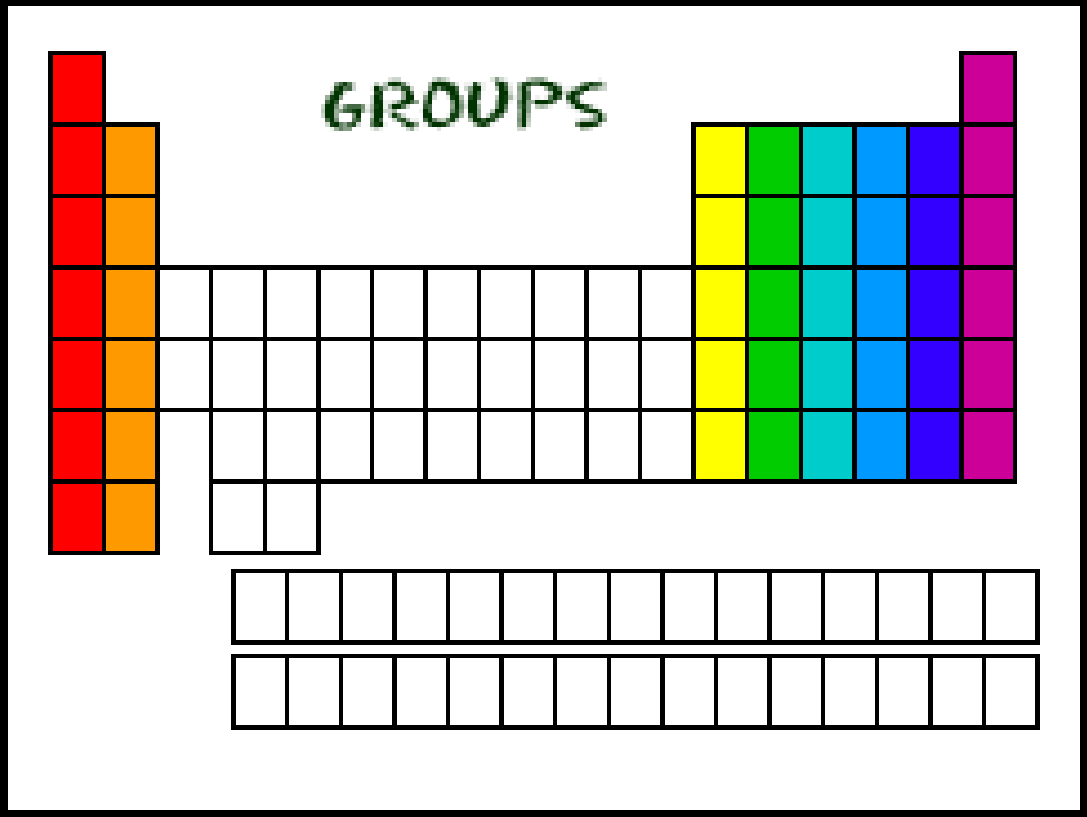
Periods

Horizontal rows called periods. There are 7 periods.



Groups

Vertical columns are called Groups.
There are 18 Groups.



(Activity 5.3) How were the positions of cobalt and nickel resolved in the Modern Periodic Table?

Modern Periodic Table is based on the atomic number. Cobalt (27) is placed before Nickel (28) in Modern Periodic Table.

How were the positions of isotopes of various elements decided in the Modern Periodic Table?

The isotopes have same atomic number so they are placed in the same group in Modern Periodic Table

(Activity 5.3) How were the positions of cobalt and nickel resolved in the Modern Periodic Table?

Is it possible to have an element with atomic number 1.5 placed between hydrogen and helium?

No, it is not possible because atomic number is a whole number.

Where do you think should hydrogen be placed in the Modern Periodic Table?

The place of hydrogen in the Modern Periodic Table is correct.

(Activity 5.4) Look at the group 1 of the Modern Periodic Table, and name the elements present in it.

The elements in group 1 are: Hydrogen (H), Lithium (Li), Sodium (Na), Potassium (k), Rubidium (Rb), Cesium (Cs) and Francium (Fr).

Write down the electronic configuration of the first three elements of group 1.

(i) H (1) 1 (ii) Li(3) 2, 1 (iii) Na (11) 2, 8, 1

What similarity do you find in their electronic configurations?

All the elements have same number of valence electron, i.e. 1

How many valence electrons are present in these three elements?

One (1)

(Activity 5.5) If you look at the long form of the Periodic Table, you will find that the elements Li, Be, B, C, N, O, F, and Ne are present in the second period.

Write down their electronic configuration.

Li (3) 2,1 Be (4) 2, 2 B (5) 2, 3 C (6) 2, 4

N (7) 2, 5 O (8) 2, 6 F (9) 2, 7 Ne (10) 2, 8

Do these elements also contain the same number of valence electrons?

No

Do they contain the same number of shells?

Yes. The elements of same periods have same number of shells but not same number of valence electrons, which increases by 1

(Activity 5.6) How do you calculate the valency of an element from its electronic configuration?

Valency of metal: It is same as the number of valence electron i.e. 1, 2, and 3.

Valency of non-metal: Valency of non-metals can be calculated by subtracting number of valence electrons from 8 (i.e. 8- number of valence electrons).

For example:

8 - 4 = 4 8 - 5 = 3 8 - 6 = 2 8 - 7 = 1 8 - 8 = 0

What is the valency of magnesium with atomic number 12 and sulphur with atomic number 16?

Magnesium (12) 2, 8, 2 Sulphur (16) 2, 8, 6

The valency of Magnesium is same as valence electron, i.e. 2.

The valency of Sulphur is

8-6 = 2 because it is non-metal.

How does the valency vary in a period on going from left to right?

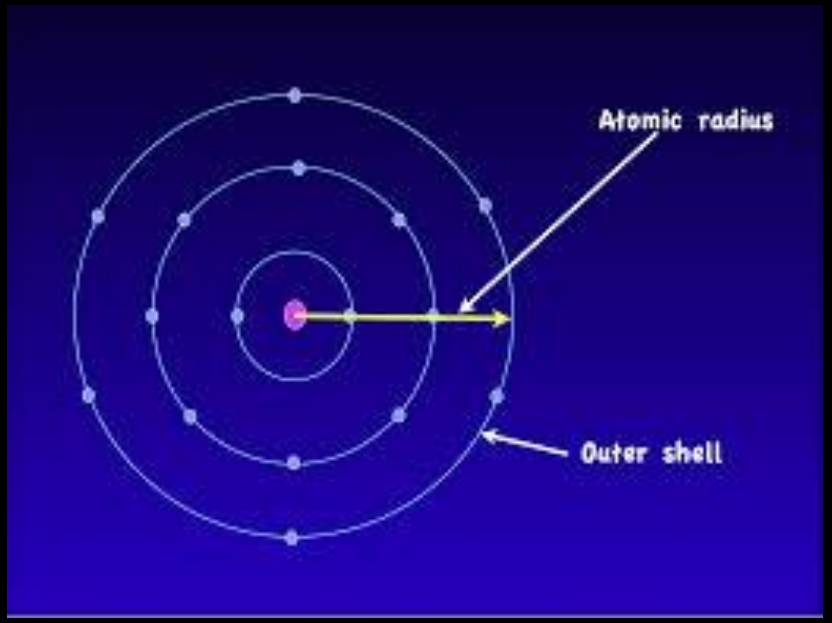
Valency first increases 1 to 4 then decreases from 4 to 0 (1, 2, 3, 4, 3, 2, 1, 0).

How does the valency vary in going down a group?

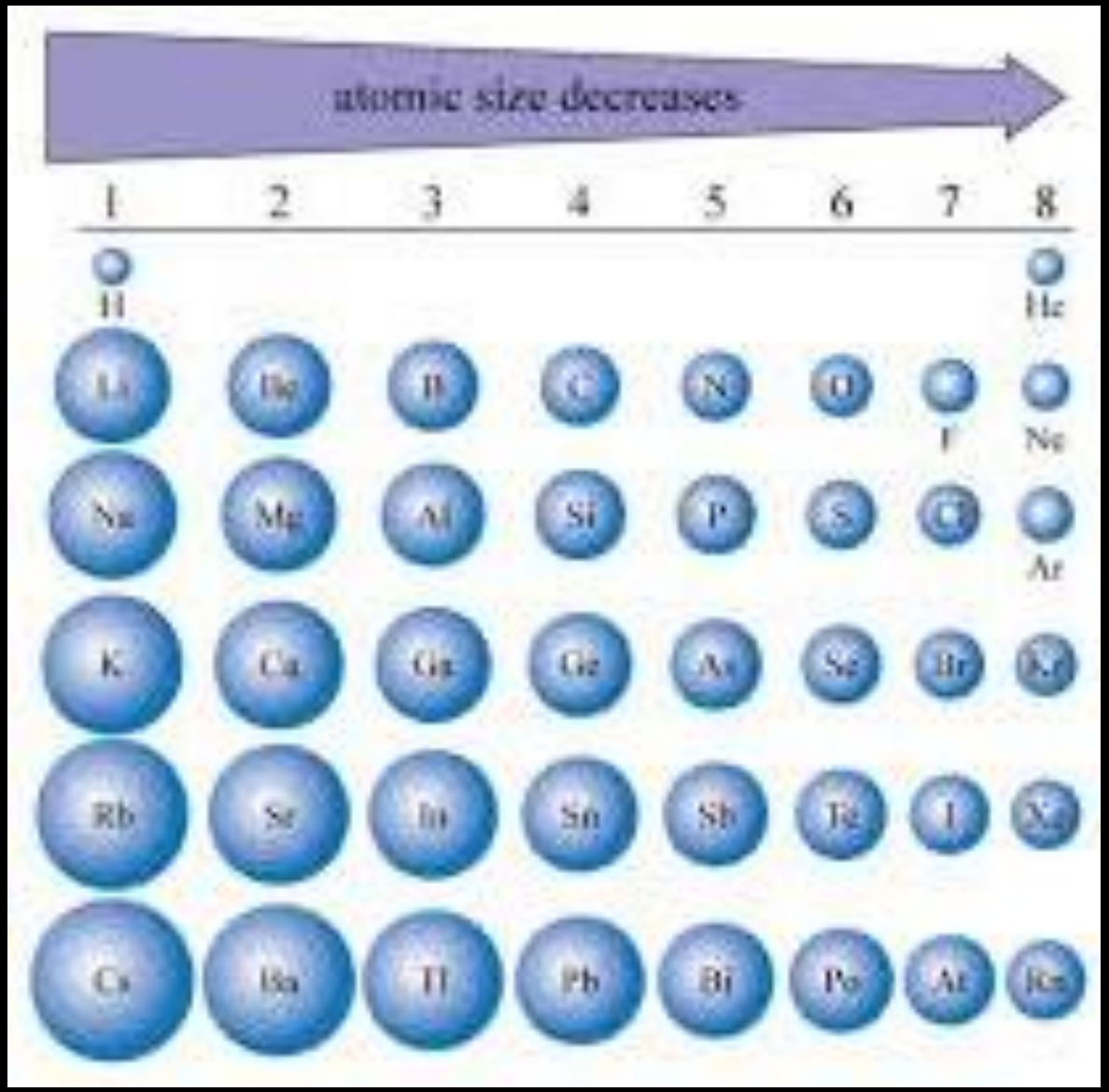
Valency remains the same because valence electrons do not change on going down in a group.

Atomic size

The distance between the centre of the nucleus and the outermost electron shell of an atom is called atomic size. It refers to the radius of the atom.



Atomic size



Atomic size decreases as we move from left to right along a period.

Atomic size

As the attraction between the (+) nucleus and the (–) valence electrons ↑, the atomic size ↓.

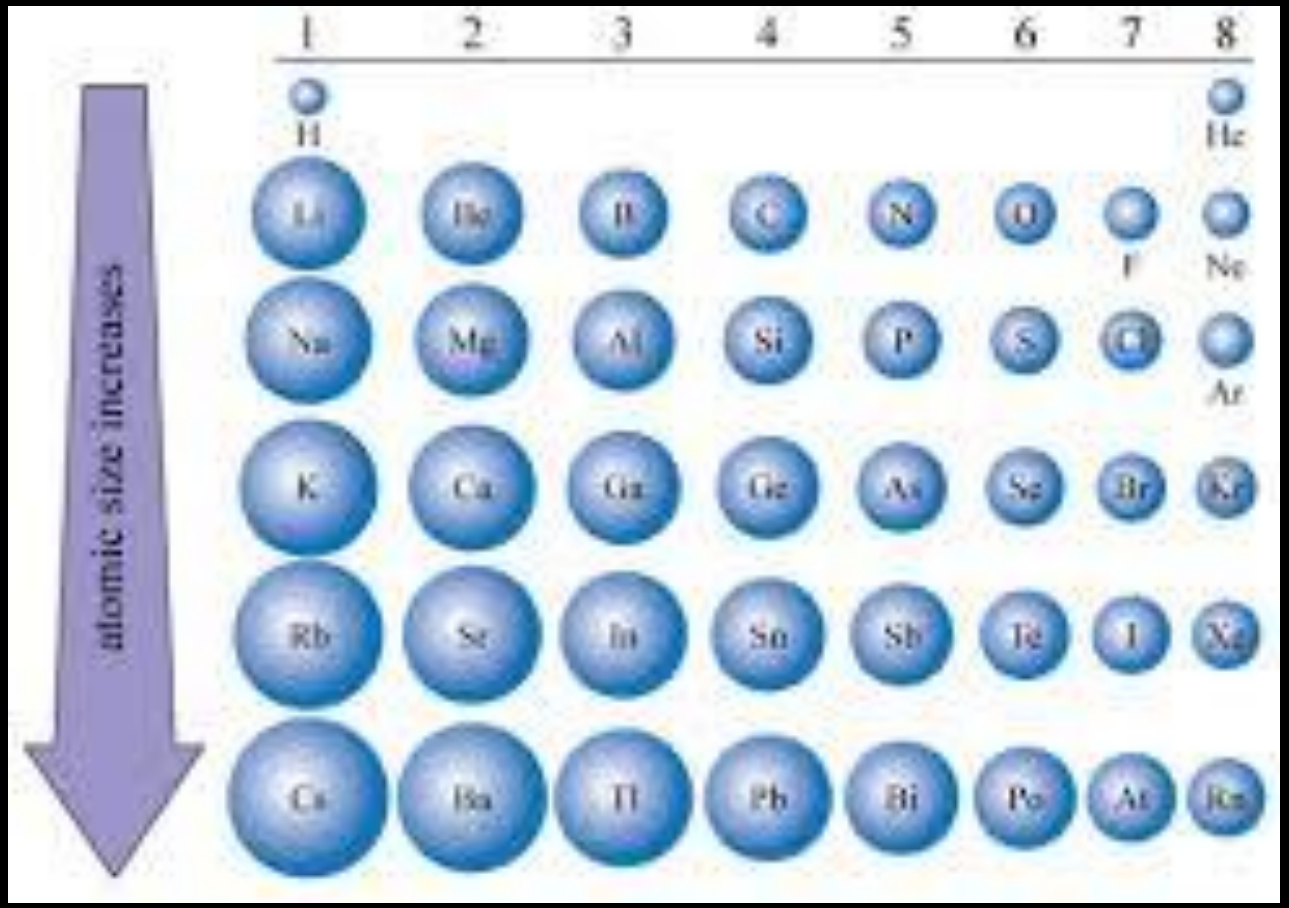
From left to right, size decreases because there is an increase in nuclear charge and Effective Nuclear Charge (# protons – # core electrons).

Each valence electron is pulled by the full Effective Nuclear Charge.

Li	Be	B
$1s^2 2s^1$	$1s^2 2s^2$	$1s^2 2s^2 2p^1$

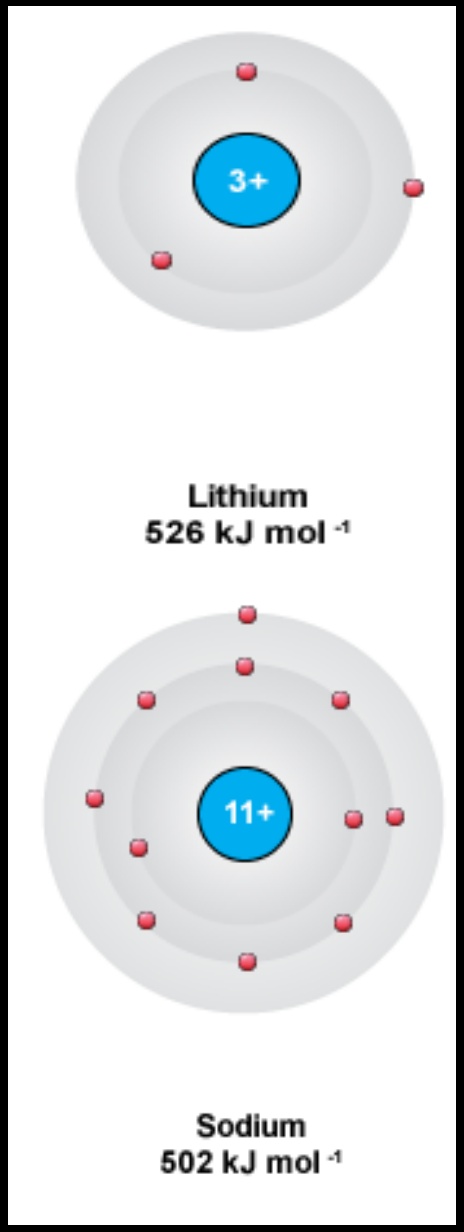
Electrons are added to the same shell

Atomic size



Atomic size increases as we go down a group.

Atomic size



Down the group new shell is added to the atom.

(Activity 5.8) Study the variation in the atomic radii of first group elements given below and arrange them in an increasing order.

Group 1 Elements	Na	Li	Rb	Cs	K
Atomic Radius (pm)	186	152	244	262	231

Group 1 Elements	Na	Li	K	Rb	Cs
Atomic Radius (pm)	186	152	231	244	244

Name the elements which have the smallest and the largest atoms.

Na (Sodium) has smallest atom. Ca (Calcium) has largest atom.

(Activity 5.9) Examine elements of the third period and classify them as metals and non-metals.

Element	Atomic No.	Configuration	Metal / non metal
Na	11	2,8,1	Metal
Mg	12	2,8,2	Metal
Al	13	2,8,3	Metal
Si	14	2,8,4	Non Metal
P	15	2,8,5	Non Metal
S	16	2,8,6	Non Metal
Cl	17	2,8,7	Non Metal
Ag	18	2,8,8	Non Metal

Elements having 1, 2, 3 valence electrons are metals while elements having 4,5,6,7,8 valence electrons are non-metals.

On which side of the Periodic Table do you find the metals?

On the left side.

On which side of the Periodic Table do you find the non-metals?

On the right side.

Metallic nature

How does metallic character vary across a period?

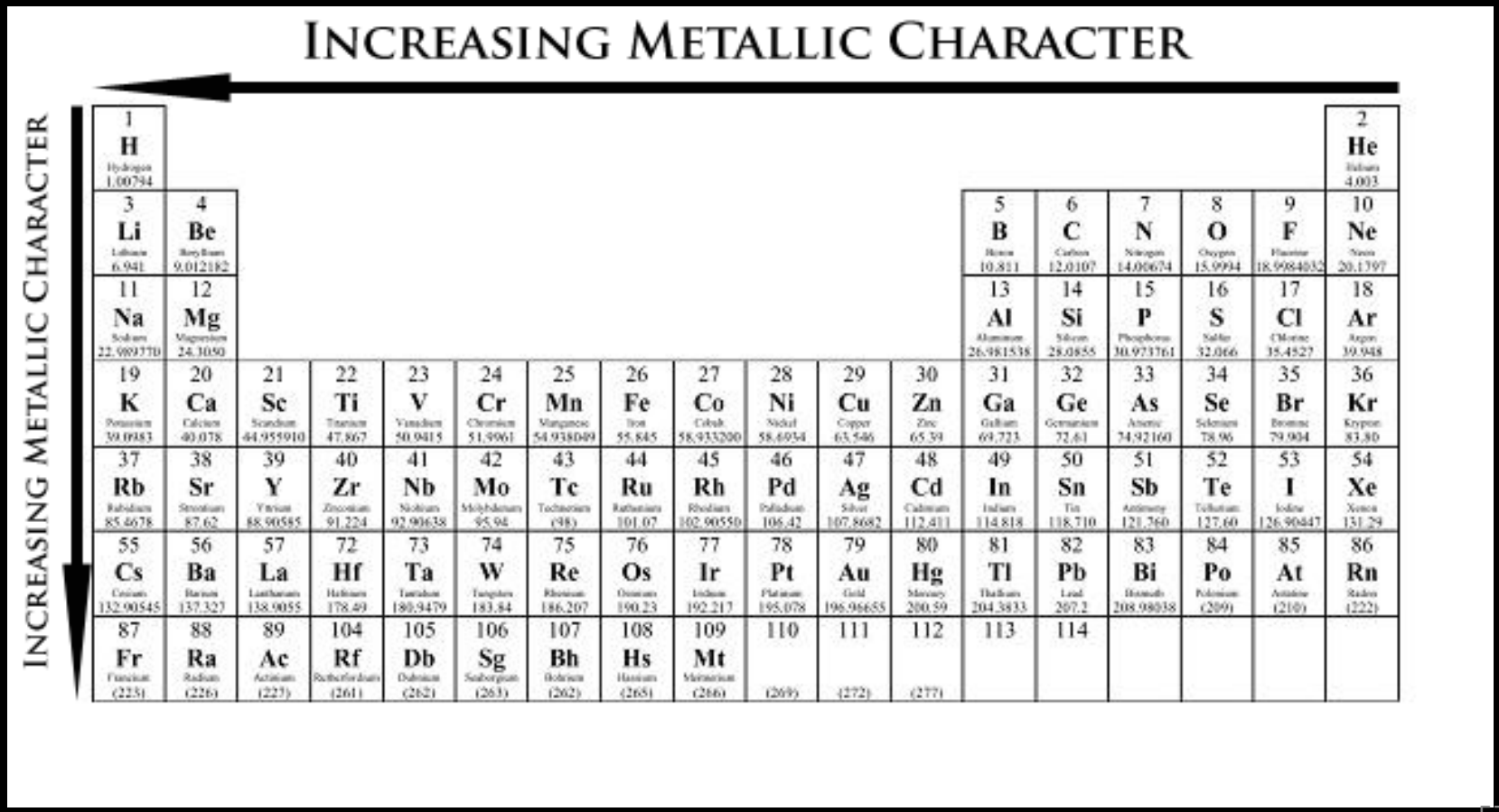
Metallic character decreases across a period.

How does metallic character vary down the group?

Metallic character increases down a group.

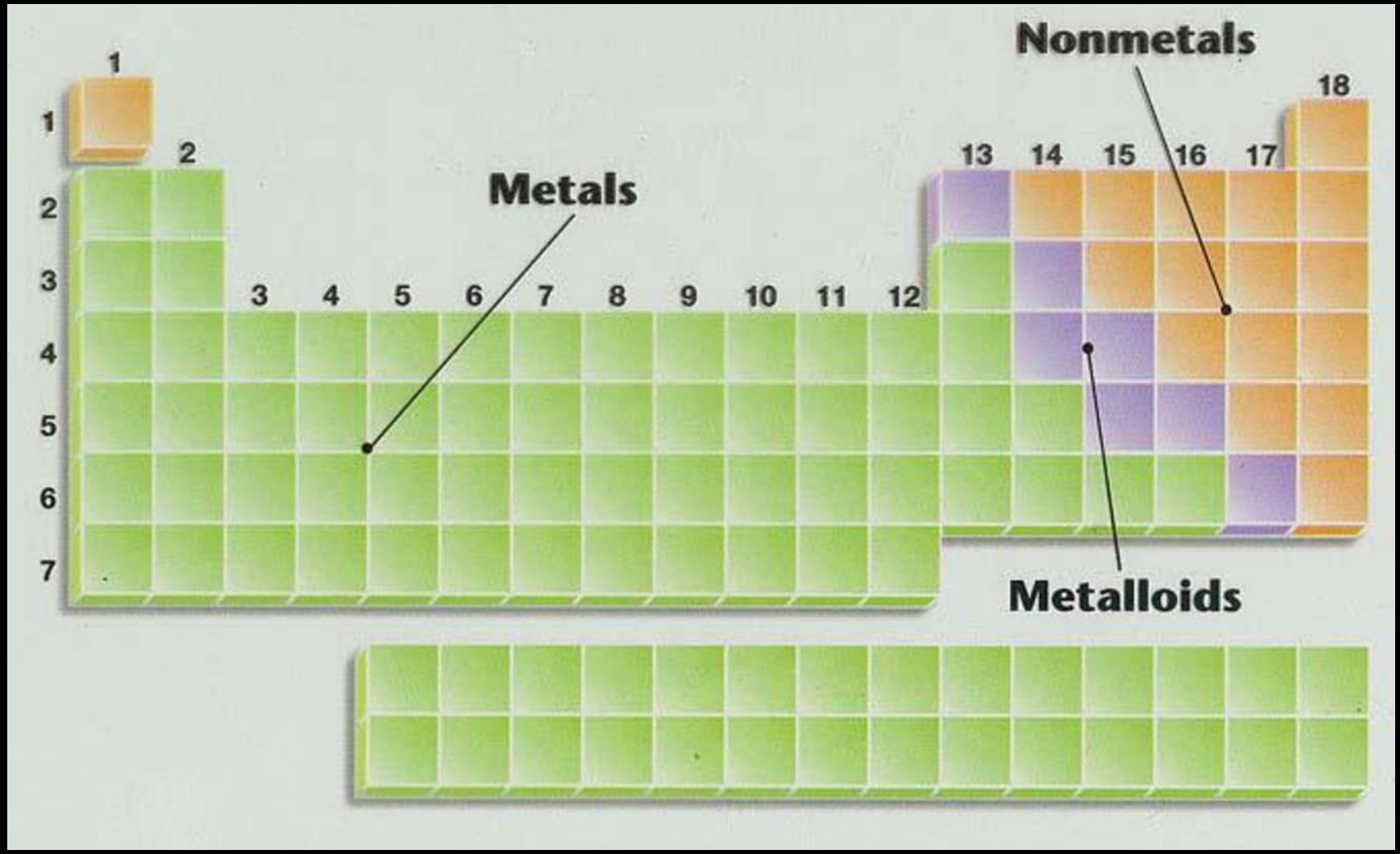
Metallic Nature

Metallic nature decreases along a period and increases down the group.



1 H Hydrogen 1.00794																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012182											5 B Boron 10.811	6 C Carbon 12.0107	7 N Nitrogen 14.00674	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797
11 Na Sodium 22.989770	12 Mg Magnesium 24.3050											13 Al Aluminum 26.981538	14 Si Silicon 28.0855	15 P Phosphorus 30.973761	16 S Sulfur 32.066	17 Cl Chlorine 35.4527	18 Ar Argon 39.948
19 K Potassium 39.0983	20 Ca Calcium 40.078	21 Sc Scandium 44.955910	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938049	26 Fe Iron 55.845	27 Co Cobalt 58.933200	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.39	31 Ga Gallium 69.723	32 Ge Germanium 72.61	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.80
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57 La Lanthanum 138.9055	72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.078	79 Au Gold 196.96655	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98038	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (263)	107 Bh Bohrium (262)	108 Hs Hassium (265)	109 Mt Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				

Metallic Nature



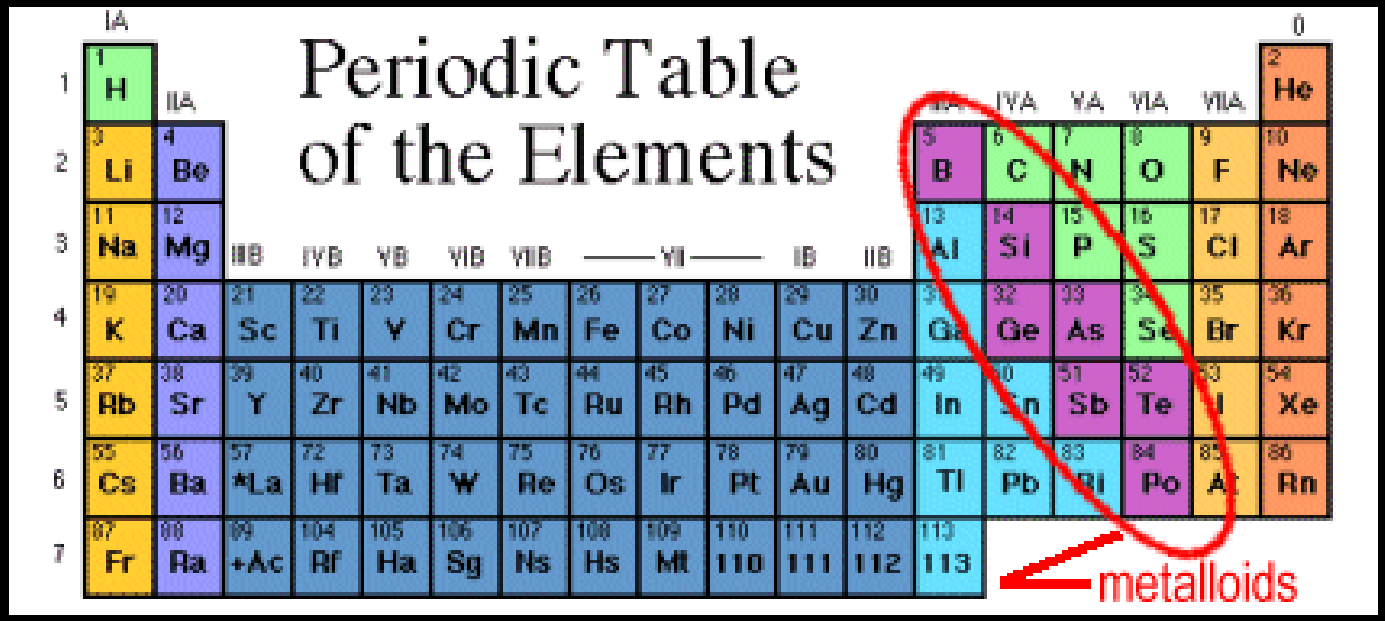
Metalloids

Elements that exhibits some properties of both metals and non-metals are called semi-metals or metalloids.

Ex: boron, silicon, germanium, arsenic, antimony, tellurium and polonium

Metalloids

Elements which are not distinctively metals and possess some physical properties of non-metals are called metalloids.



boron (B),
silicon (Si),
germanium(Ge),
arsenic (As),
antimony (Sb),
tellurium (Te),
polonium (Po)
astatine (At)

(Activity 5.10) How do you think the tendency to lose electrons will change in a group?

The tendency of lose electrons increases in a group on going down.

How will this tendency change in a period?

The tendency of lose electrons decreases as we go left to right in a period.

(Activity 5.11) How would the tendency to gain electrons change as you go from left to right across a period?

The tendency of gaining electrons increases as we go left to right in a period upto 17th group. It decreases in 18th group.

How would the tendency to gain electrons change as you go down a group?

The tendency of gaining the electrons decreases as we go down a group.

How does the trends of the periodic table help predict the nature of oxides of elements?

The trends of periodic table help us to predict the nature of oxides formed by the elements because it is known that the oxides of metals are basic and that of non-metals are acidic.

How could the Modern Periodic Table remove various anomalies of Mendeléev's Periodic Table?

I. In Modern Periodic Table, the place of hydrogen is justified because it is electropositive and so it is placed in first group with metals.
II. In Modern Periodic Table, the elements are arranged on the basis of atomic number. So the place of isotopes is also justified as the atomic number remain same of all the isotopes.
III. The order of heavy and light elements is also corrected in the Modern Periodic Table
IV. The position of inert gases is also justified.

Name:

(a) three elements that have a single electron in their outermost shells.

Lithium (li), Sodium (Na),Potassium (k)

(b) two elements that have two electrons in their outermost shells.

Magnesium (mg), Calcium (ca), Barium (Ba)

(c) three elements with filled outermost shells.

Helium (He), Neon (Ne), Argon (Ar).

(a) Lithium, sodium, potassium are all metals that react with water to liberate hydrogen gas. Is there any similarity in the atoms of these elements?

Lithium, sodium and potassium atoms have same number of electrons in their outermost shell and have same valency.

(b) Helium is an unreactive gas and neon is a gas of extremely low reactivity. What, if anything, do their atoms have in common?

Helium and neon both have their outermost shell filled.

In the Modern Periodic Table, which are the metals among the first ten elements?

Lithium, Beryllium, Boron are the metals in Modern Periodic Table among the first ten elements.

By considering their position in the Periodic Table, which one of the following elements would you expect to have maximum metallic characteristic?

Ga Ge As Se Be

Be has the maximum metallic characteristics because all other elements are situated at the right hand side in periodic table than Be. Due to the position their metallic characteristics decreases as we go from left to right.

Which element has:

(a) two shells, both of which are completely filled with electrons?

Neon (Ne), Neon has two completely filled shells with 2 electrons in K shell and 8 electrons in L shell.

(b) the electronic configuration 2, 8, 2?

Magnesium (Mg)

(c) a total of three shells, with four electrons in its valence shell?

Silicon (Si). Silicon has a total of three shells. K shell has 2 electrons, L has 8 and M i.e. valence shell has 4 electrons.

(d) a total of two shells, with three electrons in its valence shell?

Boron (B). It has a two shells, with 3 electrons in its L i.e. valence shell and 2 electrons in K shell

(e) twice as many electrons in its second shell as in its first shell?

Carbon (C) has electronic configuration of 2 electrons in K shell and 4 electrons in L shell. Clearly, it has twice as many electrons in its second shell as in its first shell.

(a) What property do all elements in the same column of the Periodic Table as boron have in common?

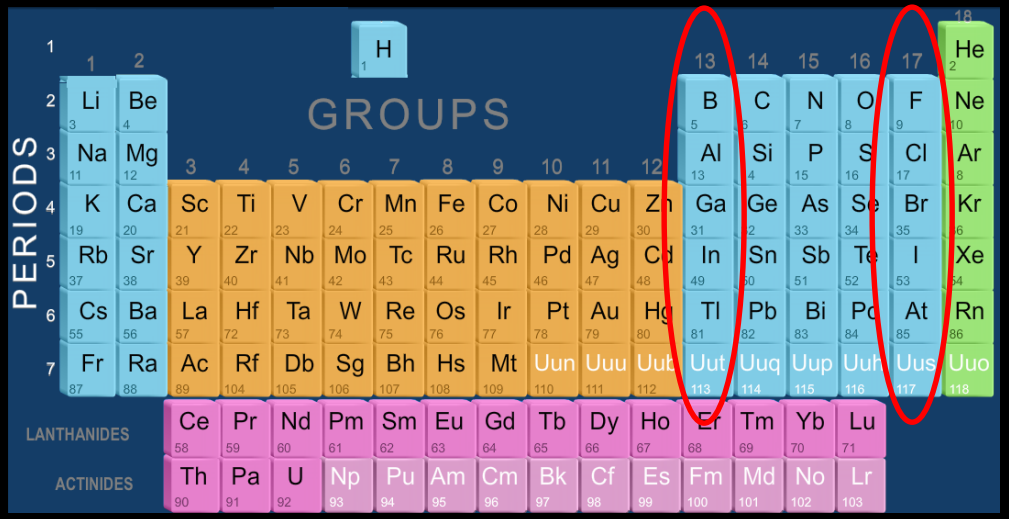
Both the elements are metals and show the following common properties:

(i) Both are good conductor of electricity. (ii) Both show malleability

(b) What property do all elements in the same column of the Periodic Table as fluorine have in common?

Both the elements are non-metal and show following common properties:

(i) Both are brittle (ii) Both are bad conductor of electricity.



An atom has electronic configuration 2, 8, 7. (Atomic numbers are given in parentheses.) N(7) F(9) P(15) Ar(18)

(a) What is the atomic number of this element?

The atomic number of element is 17

(b) To which of the following elements would it be chemically similar?

It belongs chemically to F(9) because the electronic configuration of F is 2, 7 and having same valence electrons.

The position of three elements A, B and C in the Periodic Table are shown below –

Group 16	Group 17
-	-
-	A
-	-
B	C

(a) State whether A is a metal or non-metal.

C is non-metal because it belongs to 17th group.

(b) State whether C is more reactive or less reactive than A.

C is less reactive than A because the reactivity of non-metal decreases from top to bottom.

(c) Will C be larger or smaller in size than B?

The size of C is smaller than B because B and C belong to the same period and the size decreases in a period on going left to right

(d) Which type of ion, cation or anion, will be formed by element A?

A forms anion because C is non-metals for anion (Negative Ion)

Nitrogen (atomic number 7) and phosphorus (atomic number 15) belong to group 15 of the Periodic Table. Write the electronic configuration of these two elements. Which of these will be more electronegative? Why?

Atomic number of Nitrogen is 7 and electronic configuration is 2, 5.

Atomic number of Phosphorus is 15 and electronic configuration is 2, 8, 5.

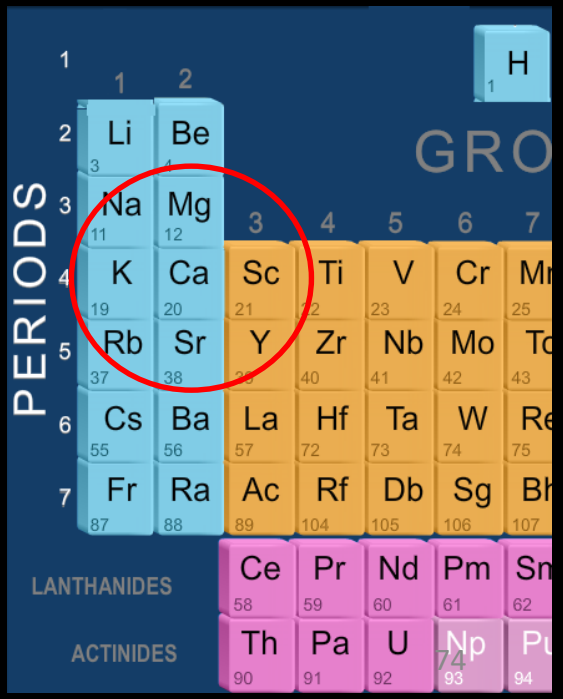
Phosphorus will be more electronegative because phosphorus and nitrogen both are non-metals. Phosphorus is situated in the lower side than Nitrogen. In non-metals, as we go top to bottom the electronegativity is increased.

In the Modern Periodic Table, calcium (atomic number 20) is surrounded by elements with atomic numbers 12, 19, 21 and 38. Which of these have physical and chemical properties resembling calcium?

Atomic number of Calcium is 20 and its electronic configuration is 2, 8, 8, 2. To see the resemblance with Calcium, first we have to check the Electronic Configuration of respective elements.

Element with Atomic Number - 12 2, 8, 2
Element with Atomic Number - 19 2, 8, 8, 1
Element with Atomic Number - 21 2, 8, 8, 3
Element with Atomic Number - 38 2, 8, 18, 8, 2

From above, it is clear, elements with atomic number 12 and 38 has same electronic configuration of valence shell as that of Calcium, and therefore, will have physical and chemical properties resembling calcium



Exercise (MCQ)

1. Which of the following statements is not a correct statement about the trends when going from left to right across the periods of periodic Table?

(a) The elements become less metallic in nature.
(b) The number of valence electrons increases.
(c) The atoms lose their electrons more easily.
(d) The oxides become more acidic.

2. Element X forms a chloride with the formula XCl_2, which is a solid with a high melting point. X would most likely be in the same group of the Periodic Table as:

(a) Na
(b) Mg
(c) Al
(d) Si

END