Chapter 3

Periodic Properties

Day - 1

INTRODUCTION

In 1800, only 31 elements were known. By 1865, the number of identified elements had more than doubled to 63. At present 114 elements are known.

With such a large number of elements it is very difficult to study individually. the chemistry of all these elements is also difficult to handle individually.

LAW OF TRIADS

Johann Döbereiner classified elements in group of three elements called triads.

In Döbereiner triad the atomic weight of the middle element is very close to the arithmetic mean of the other two elements

Element	Atomic Weight	Element	Atomic Weight	Element	Atomic Weight
Li	7	Ca	40	Cl	35.5
Na	23	Sr	88	Br	80
K	39	Ba	137	I	127

LAW OF OCTAVES

Since Döbereiner Law of triads worked only for few elements, it was dismissed.

Chancourtois arranged elements in order of increasing atomic weights and made a cylindrical table of elements.

John Newland arranged the elements in the increasing order of atomic weight and noted that the properties of the every eighth element are similar to the first one. This relationship is called as “Law of octaves”

Element	**Li**	**Be**	**B**	**C**	**N**	**O**	**F**
At.wt	7	9	11	12	14	16	19
Element	**Na**	**Mg**	**Al**	**Si**	**P**	**S**	**Cl**
At.wt.	23	24	27	29	31	32	35.5
Element	**K**	**Ca**					
At.wt.	39	40					

MENDELEEV’S PERIODIC TABLE

According to Mendeleev’s periodic law the physical and chemical properties of elements are periodic functions of their atomic weights.

Merits of Mendeleev’s periodic table:

- Mendeleev’s periodic table was very helpful in remembering and studying the properties of large number of elements

- Mendeleev's periodic table helped in correcting the atomic masses of some of the elements like gold, beryllium and platinum based on their positions in the periodic table
- Mendeleev could predict the properties of some undiscovered elements like scandium, gallium and germanium. By this intuition, he had left gaps for the undiscovered elements while arranging elements in his periodic table

	Gruppe I R^1O	Gruppe II RO	Gruppe III R^1O^3	Gruppe IV RH^4 RO^7	Gruppe V RH^4 R^2O^5	Gruppe VI RH^4 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.	N = 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 C0 = 59 Ni = 60, 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 = 56	- = 100	Ru = 104, Rh = 104, Pd = 106, ag = 104.
7.	(Ag = 104)	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, lr = 197, Pt = 198, Au = 199.
11.	(Au = 199)	Hg = 200	Tl = 204	Pb = 207	Bi = 208	-	-	
12.	-	-	-	Th = 231	-	U = 240	-	- - - - - - - -

SUCCESS OF MENDELEEV'S WORK

Property	Eka-aluminium	Gallium (found)	Eka-silicon (predicted)	Germanium (found)
Atomic weight	68	70	72	72.6
Density (g/cm^3)	5.9	5.94	5.5	5.36
Melting point /K	Low	302.93	High	1231
Formula of oxide	E_2O_3	$Ga_2\ O_3$	EO_2	GeO_2
Formula of chloride	ECl_3	$GaCl_3$	ECl_4	$GeCl_4$

Limitation of Mendeleev's table

- Position of hydrogen is not correctly defined in periodic table. It is placed in group I though it resembles both group 1 and 17.
- In certain pairs of elements increasing order of atomic masses was not obeyed. For example argon (Ar, atomic mass 39.9) is placed before potassium (K, atomic mass 39.1)
- Isotopes were not given separate places in the periodic table although Mendeleev's classification is based on the atomic masses.
- Some similar elements are separated and dissimilar elements are grouped together. For example copper and mercury resembled in their properties but had been placed in different groups. On the other hand lithium and copper were placed together although their properties are quite different.
- Mendeleev did not explain the cause of periodicity among the elements.
- Lanthanoids and actinoids were not given a separate position in the table.

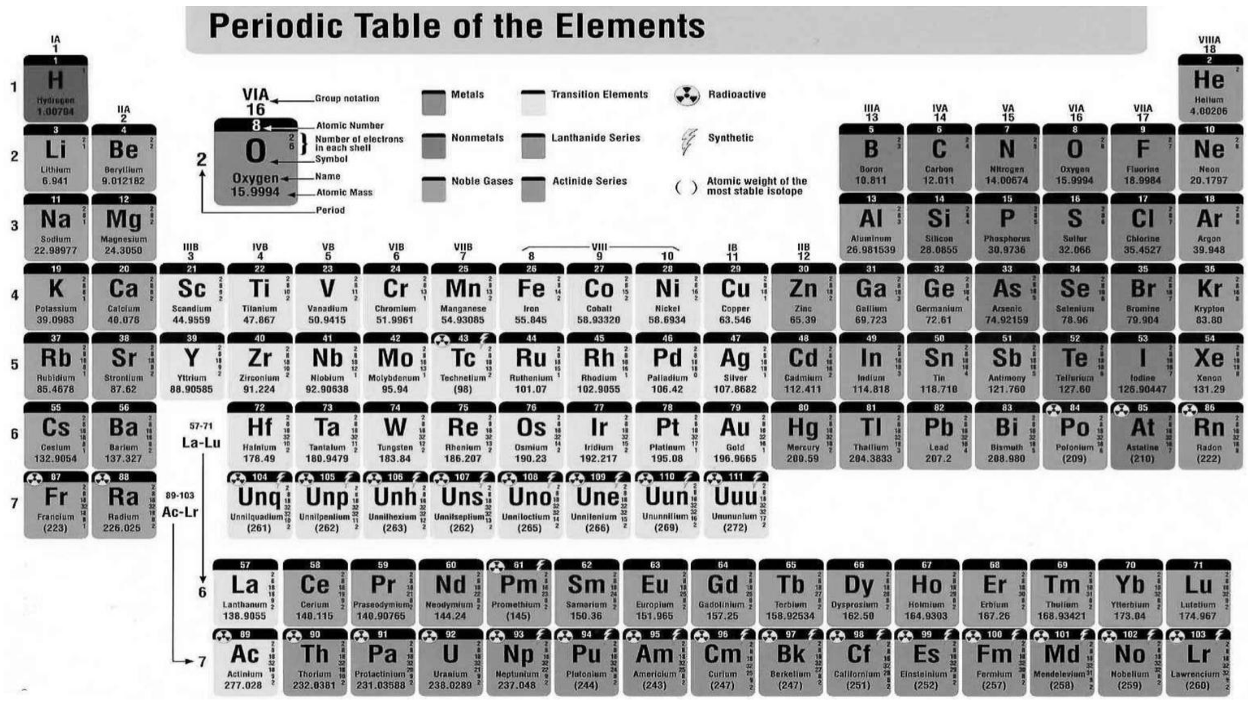
Modern Periodic Table

Henry Moseley *showed* that the atomic number is a more fundamental property of an element than its atomic mass.

Mendeleev's Periodic Law was, therefore, accordingly modified.

Modern Periodic Law:

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



Nomenclature of elements of Atomic mass > 100

Digit	Name	Abbreviation
0	nil	n
1	un	u
2	bi	b
3	tri	t
4	quad	q
5	pent	p
6	hex	h
7	sept	s
8	oct	o
9	enn	e

Atomic Number	Name	Symbol	IUPAC Official Name	IUPAC Symbol
101	Unnilunium	Unu	Mendelevium	Md
102	Unnilbium	Unb	Nobelium	No

Electronic Configurations for Periods and groups

Electronic configuration of Zirconium (A. No. 40): $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^2$

Iodine $I_{53} = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^5$

We can classify the elements into four blocks *viz.,*

s-block, p-block, d-block and f-block depending on the type of atomic orbitals that are being filled with electrons.

Hydrogen and Helium are exception to this rule

The *s-Block Elements*

The elements of Group 1 (alkali metals) and Group 2 (alkaline earth metals) which have ns^1 and ns^2 *outermost electronic configuration* belong to the ***s-Block Elements.***

The *p-Block Elements*

The outermost electronic configuration varies from ns^2np^1 to ns^2np^6 in each period. The p-Block Elements comprise those belonging to Group 13 to 18 and these together with the s-Block Elements are called the Representative Elements or Main Group Elements.

The *d-Block Elements (Transition* Elements)

These elements have the general outer electronic configuration $(n\text{-}1)d^{1\text{-}10}ns^{0\text{-}2}$. These are the elements of Group 3 to 12 in the centre of the Periodic Table. These are characterised by the filling of inner *d orbitals* by electrons and are therefore referred to as ***d-Block Elements.*** *They are all metals.*

The *f-Block Elements* (Inner-Transition Elements)

They have outer electronic configuration $(n\text{-}2)f^{1\text{-}14}\ (n\text{-}1)d^{0\text{-}1}ns^2$

The two rows of elements at the bottom of the Periodic Table, called the Lanthanoids, Ce(*Z = 58) to Lu(Z = 71) and Actinoids,* Th(*Z = 90) to Lr (Z = 103)* **.**

METALS, NON METALS AND METALLOIDS

Metals comprise more than 78% of all known elements and appear on the left side of the Periodic Table. Metals are usually solids at room temperature [mercury is an exception; gallium and caesium also have very low melting points (303K and 302K, respectively)]. Metals usually have high melting and boiling points. They are good conductors of heat and electricity. They are malleable (can be flattened into thin sheets by hammering) and ductile (can be drawn into wires). In contrast, non-metals are located at the top right hand side of the Periodic Table. In fact, in a horizontal row, the property of elements change from metallic on the left to non-metallic on the right. Non-metals are usually solids or gases at room temperature with low melting and boiling points (boron and carbon are exceptions). They are poor conductors of heat and electricity.

Most non-metallic solids are brittle and are neither malleable nor ductile. The elements become more metallic as we go down a group; the non-metallic character increases as one goes from left to right across the **Periodic Table. The** change from metallic to non-metallic character is not abrupt as shown by the thick zigzag line in periodic table.

The elements (e.g., silicon, germanium, arsenic, antimony and tellurium) bordering this line and running diagonally across the **Periodic Table show properties that** are characteristic of both metals and non-metals. These elements are called **Semi-metals** or **Metalloids**

SHIELDING EFFECT

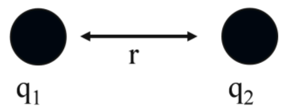
Shielding effect or screening effect: Due to the presence of electrons in the inner shells, the electron in the outer shell will not experience the full positive charge on the nucleus.

So due to the screening effect, the net positive charge experienced by the electron from the nucleus is lowered and is known as effective nuclear charge.

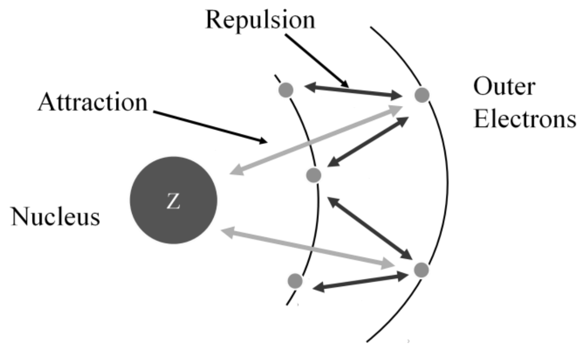
- Effective nuclear charge, Z_{eff}, experienced by an electron is less than actual nuclear charge , Z

- Electrons in the outermost shell are repelled (shielded) by electrons in the inner shells. This repulsion counteracts the attraction caused by the positive nuclear charge

Coulomb's law:



SHIELDING EFFECT



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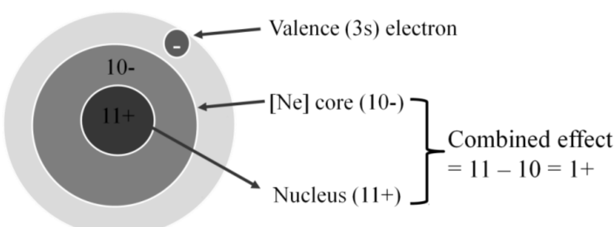
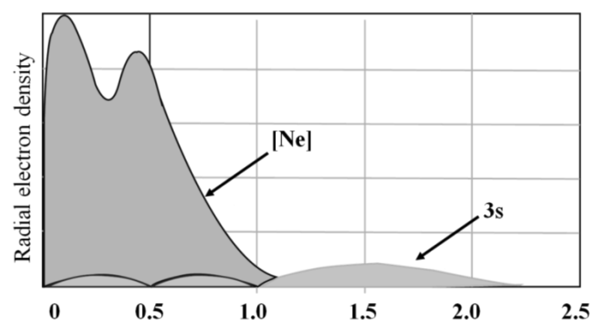
$\mathbf{Z}_{eff} = Z - S$ (S = screening constant)

Shielding effect

(1) Electrons in inner orbitals have greater shielding effect than electrons in same shell.

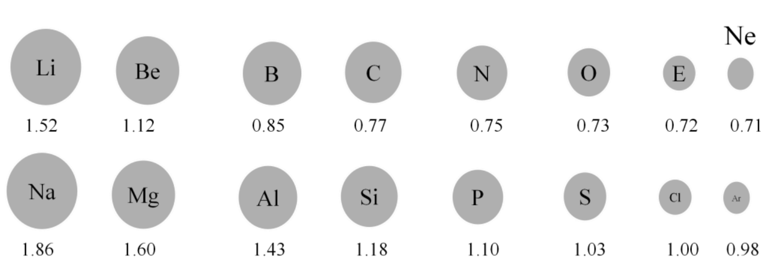
(2) Shielding effect s > p > d > f



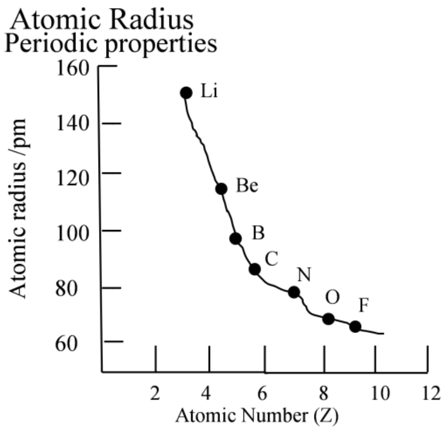


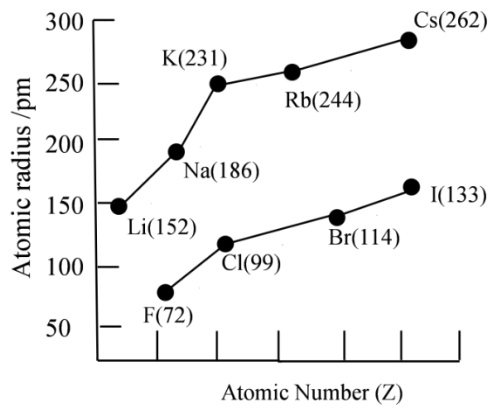
ATOMIC RADII

Periodicity

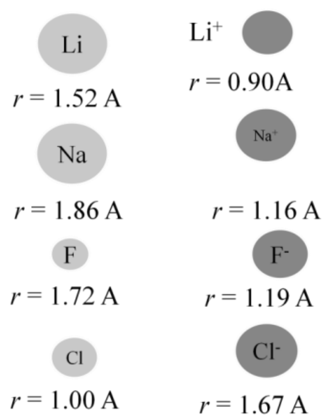


- As we move from left to right along the period, the effective nuclear charge "felt" by the outermost electron increases while the distance from the nucleus doesn't change that much (electrons are filling the same shell)
- Outermost electrons are attracted stronger by the nucleus, and the atomic radius decreases





IONIC RADII



When atom loses an electron, its radius always decreases

- Cations (positive ions) are always smaller than their respective neutral atoms.

When atom gains an electron, its radius always increases

- Anions (negative ions) are always larger than their respective neutral atoms

ISOELECTRONIC SPECIES

- Species of different elements having the same electron configuration
- N $[He]2s^22p^3$ N^{3-} $[He]2s^22p^6$
- O $[He]2s^22p^4$ O^{2-} $[He]2s^22p^6$
- F $[He]2s^22p^5$ F^- $[He]2s^22p^6$
- Ne $[He]2s^22p^6$ Ne $[He]2s^22p^6$
- Mg $[He]2s^22p^63s^2$ Mg^{2+} $[He]2s^22p^6$
- Al $[He]2s^22p^63s^23p^1$ Al^{3+} $[He]2s^22p^6$