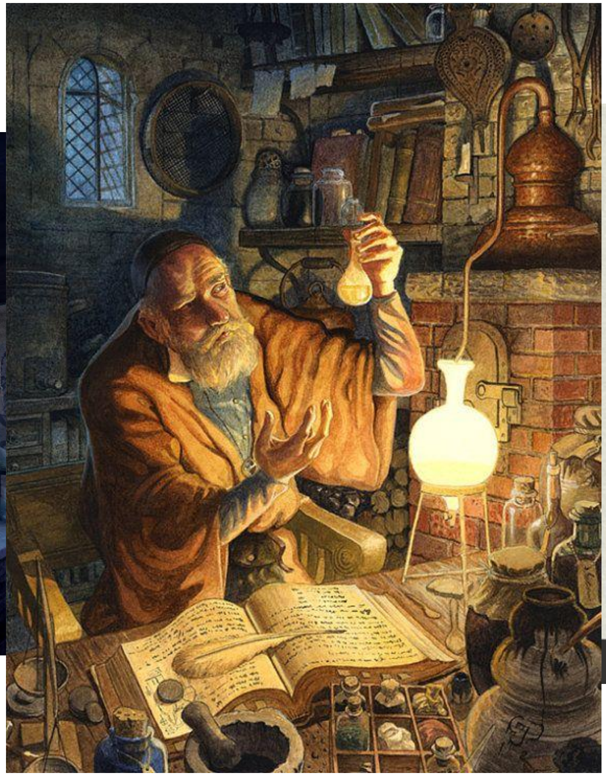
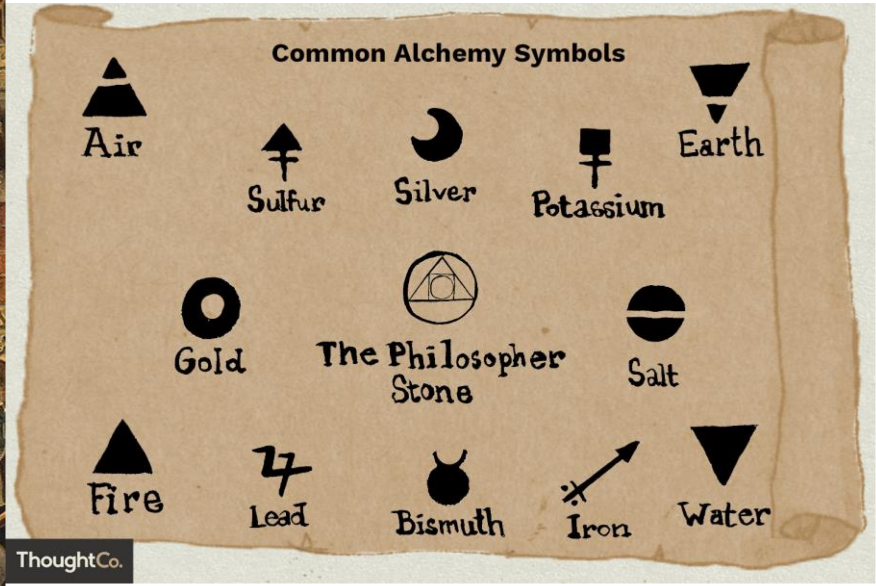
PERIODIC TABLE OF ELEMENTS

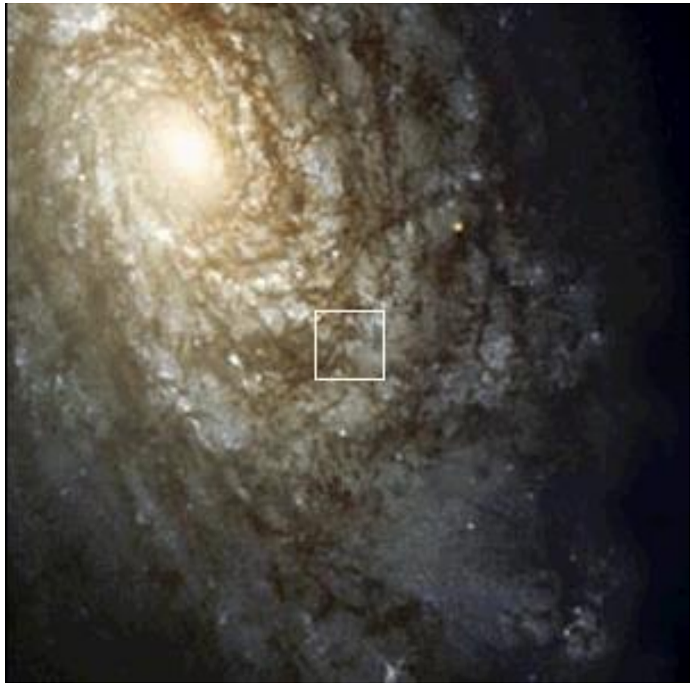




Elements

- Science has come along way since Aristotle’s theory of Air, Water, Fire, and Earth.
- Scientists have identified 90 naturally occurring elements, and created about 28 others.

The elements, alone or in combinations, make up our bodies, our world, our sun, and in fact, the entire universe.



Characteristics of Periodic table:

- The periodic table organizes the elements in a particular way. A great deal of information about an element can be gathered from its position in the period table.

- For example, you can predict with reasonably good accuracy the physical and chemical properties of the element. You can also predict what other elements a particular element will react with chemically.

- Understanding the organization and plan of the periodic table will help you obtain basic information about each of the 118 known elements.

Historical development:

1829: First successful attempt. But can not be generalized.

Dobereiner's Triads					
Element	Atomic weight	Element	Atomic weight	Element	Atomic weight
Li	6.9	Ca	40.1	Cl	35.5
Na	23.0	Sr	87.6	Br	79.9
K	39.1	Ba	137.3	I	126.9

He also pointed out the atomic weight of Fe, Co, Ni are almost same.

1858: Pettenkofer pointed out – the atomic weights of chemically similar elements differ by an integral multiple of 8.

Table 1. Some milestones of discovery of the periodic table.

Contributor	**Year**	**Contribution**
Dobereiner	1829	Classification of elements into triads [1]
Kremers	1852	Development of rational classifications of elements and regularities in their atomic weights [2-4]
Gladston	1853	
Cooke	1854	
Lenssen	1857	
Pettenkofer	1858	
Dumas	1858	
Strecker	1859	
Hinrichs	1867	
Odling	1857, 1864	Table of 43 elements arranged in 13 groups [5]
De Chancourtois	1862	Classification of elements (spiral around cylinder) with increase of their atomic weights [6]
Meyer	1864, 1871	Arranging of similar elements in groups, periodicity of atomic volumes [7]
Newlands	1865	Octaves' Law [8]
Mendeleev	1869, 1871	Periodic table; prediction of new elements and their properties; changes/improvements of known atomic weights [9,10]

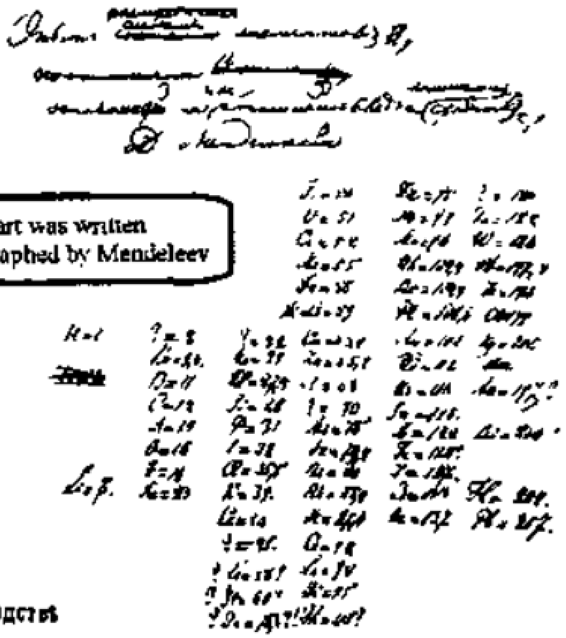
Newland’s law of octaves

sa (do)	re (re)	ga (mi)	ma (fa)	pa (so)	da (la)	ni (ti)
H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe
Co and Ni	Cu	Zn	Y	In	As	Se
Br	Rb	Sr	Ce and La	Zr	—	—

If the elements are arranged in order of increasing atomic weights, all the eighth elements have similar properties in most of the cases.

Mendeleev’s periodic law and table

The properties of the elements are the periodic functions of
Their atomic weight



The chart was written
and autographed by Mendeleev

ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ,

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ

			Ti = 50	Zr = 90	? = 180
			V = 51	Nb = 94	Ta = 182
			Cr = 52	Mo = 96	W = 186
			Mn = 55	Rh = 104,4	Pt = 197,4
			Fe = 56	Ru = 104,4	Ir = 198
			Ni = Co = 59	Pl = 106,6	Os = 199
H = 1			Cu = 63,4	Ag = 108	Hg = 200
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112	
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?
	C = 12	Si = 28	? = 70	Sn = 118	
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?
	O = 16	S = 32	Se = 79,4	Te = 128?	
	F = 19	Cl = 35,5	Br = 80	J = 127	
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207
		? = 45	Ce = 92		
		?Er = 56	La = 94		
		?Yt = 60	Di = 95		
		?In = 75,6	Th = 118?		

The table presented to the Russian
Chemical Society by Mendeleev

One century later, 1969:
A one rouble coin with Mendeleev

In 1871, with known 63 elements
At that time

Modern version of the Mendeleev's short periodic table:

H 1.01									
Li 6.94	Be 9.01	B 10.8	C 12.0	N 14.0	O 16.0	F 19.0			
Na 23.0	Mg 24.3	Al 27.0	Si 28.1	P 31.0	S 32.1	Cl 35.5			
K 39.1	Ca 40.1		Ti 47.9	V 50.9	Cr 52.0	Mn 54.9	Fe 55.9	Co 58.9	Ni 59.7
Cu 63.5	Zn 65.4			As 74.5	Se 79	Br 79.9			
Rb 85.5	Sr 87.6	Y 88.7	Zr 91.2	Nb 92.9	Mo 95.9		Ru 101	Rh 103	Pd 106
Ag 108	Cd 112	In 115	Sn 119	Sb 122	Te 128	I 127			
Ce 133	Ba 137	La 139		Ta 181	W 184		Os 194	Ir 192	Pt 195
Au 197	Hg 201	Ti 204	Pb 207	Bi 209					
			Th 232		U 238				

Groups Oxide: Hydride:	I R_2O RH	II RO RH_2	III R_2O_3 RH_3	IV RO_2 RH_4	V R_2O_5 RH_3	VI RO_3 RH_2	VII R_2O_7 RH	VIII 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 26.98	Si 28.09	P 30.0974	S 32.06	Cl 35.453	
4 First series	K 39.102	Ca 40.08	Sc 44.96	Ti 47.90	V 50.94	Cr 52.20	Mn 54.94	Fe Co Ni 55.85 58.93 58.71
Second series	Cu 63.54	Zn 65.37	Ga 69.72	Ge 72.59	As 74.92	Se 78.96	Br 79.909	
5 First series	Rb 85.47	Sr 87.62	Y 88.91	Zr 91.22	Nb 92.91	Mo 95.94	Tc 99	Ru Rh Pd 101.07 102.91 106.4
Second series	Ag 107.87	Cd 112.40	In 114.82	Sn 118.69	Sb 121.75	Te 127.60	I 126.90	
6 First series	Cs 132.90	Ba 137.34	La 138.91	Hf 178.49	Ta 180.95	W 183.85		Os Ir Pt 190.2 192.2 195.2
Second series	Au 196.97	Hg 200.59	Tl 204.37	Pb 207.19	Bi 208.98			

In the modern form of the periodic table, atomic weight is replaced by atomic number, thanks to work of Mosley.

Things to know:

Periods and groups

How many types of periods?

Very short (H, He); Short (2^{nd} and 3^{rd})
Long (4^{th} and 5^{th})
Very long (6^{th} and 7^{th})

Subgroups:

The elements in a particular subgroup are chemically similar while
Except the valency, the similarity between A and B subgroup
Elements in a particular group is lacking drastically.

For eg. Gr.IA : Li, Na, K, Rb, Cs, Fr differ drastically from the
B subgroup coinage metals : CU, Ag, Au

Gr. A are more electronegative compared to Gr. B

Triad elements: In gr VIII, there are three triads. Fe, Co, Ni /// Ru, Rh, Pd /// Os, Ir, Pt

Atomic weight is close..
The 2^{nd} and 3^{rd} are called as platinum metals

Trivial names of elements:

(i) Alkali metals: ….
(ii) Alkaline earth metals: …
(iii) Chalcogens: ….
(iv) Halogens: ….
(v) Noble gases: ….
(vi) Lanthanum series: …
(vii) Lanthanides or rare earth: …
(viii) Actinum series: …
(ix) Actinides: …
(x) Coinage metals: …
(xi) Platinum metals: …
(xii) Noble metals: …
(xiii) Transuranium metals: ….

Characteristics and classification of Mendeleev's periodic table:

i) Systematic classification of the elements
ii) Correction of atomic weights
a) Atomic weight of Be corrected
b) Atomic weight of Indium corrected

iii) Prediction of missing elements: eka silicon (Ge), eka Boron (Sc), eka-Aluminium (Ga)..

Defects in Mendeleev's periodic table:

(i) Reverse atomic weight in some cases (K-39, Ar-40); (I-127, Te-128); (Ni-58, Co-59); (Th-232, Pa-231)

(ii) Triads in Group VIII

(iii) Subgroup elements lacking in similarities

(iv) Positions of isotopes

(v) Positions of lanthanides and actinides

(vi) Position of hydrogen as it also has similarities with Gr VIIB (halogen) elements etc.

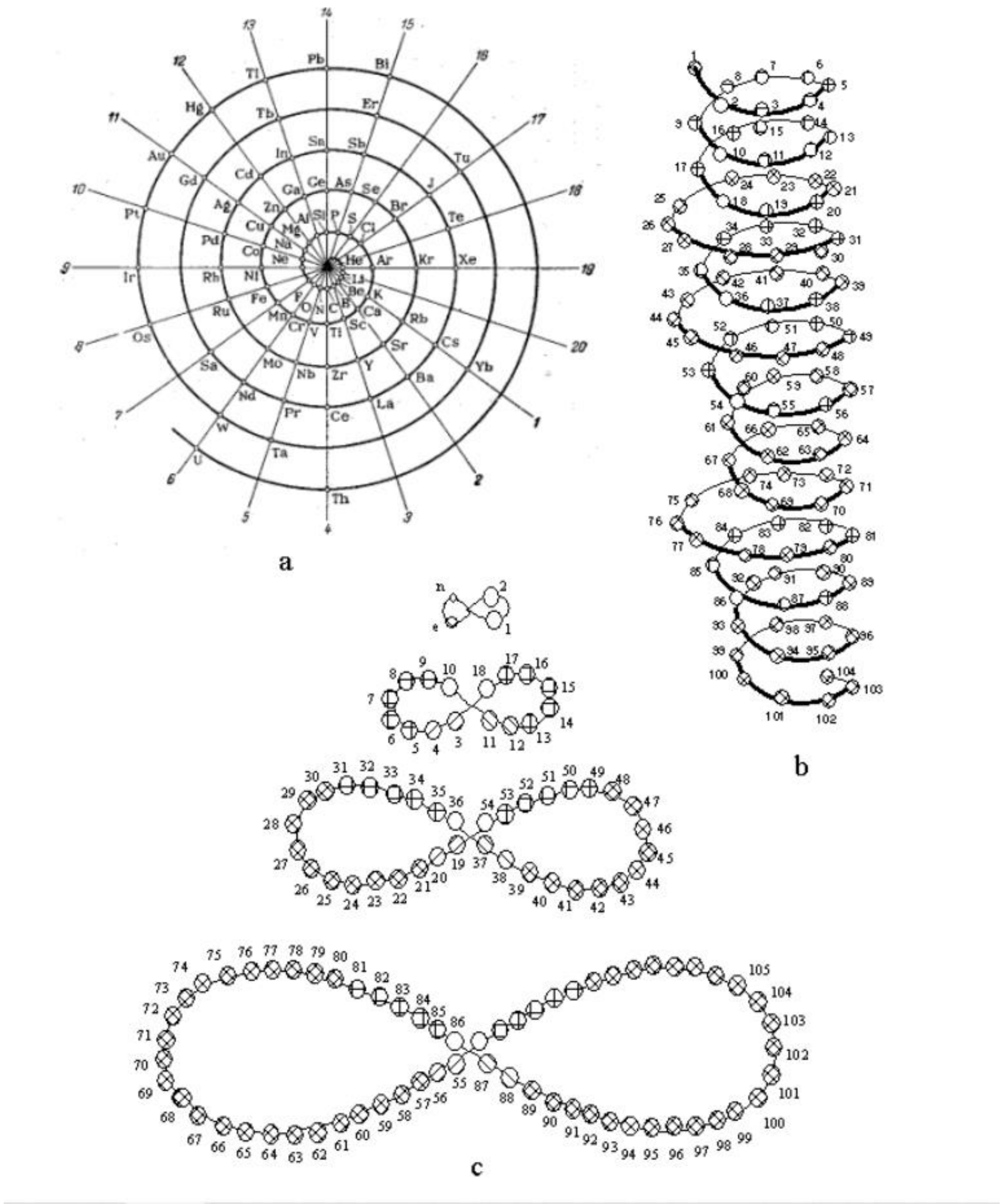
Periodic table of the elements

- Alkali metals
- Alkaline-earth metals
- Transition metals
- Other metals
- Other nonmetals
- Halogens
- Noble gases
- Rare-earth elements (21, 39, 57–71) and lanthanoid elements (57–71 only)
- Actinoid elements

period \ group	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

lanthanoid series 6	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
actinoid series 7	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

*Numbering system adopted by the International Union of Pure and Applied Chemistry (IUPAC).



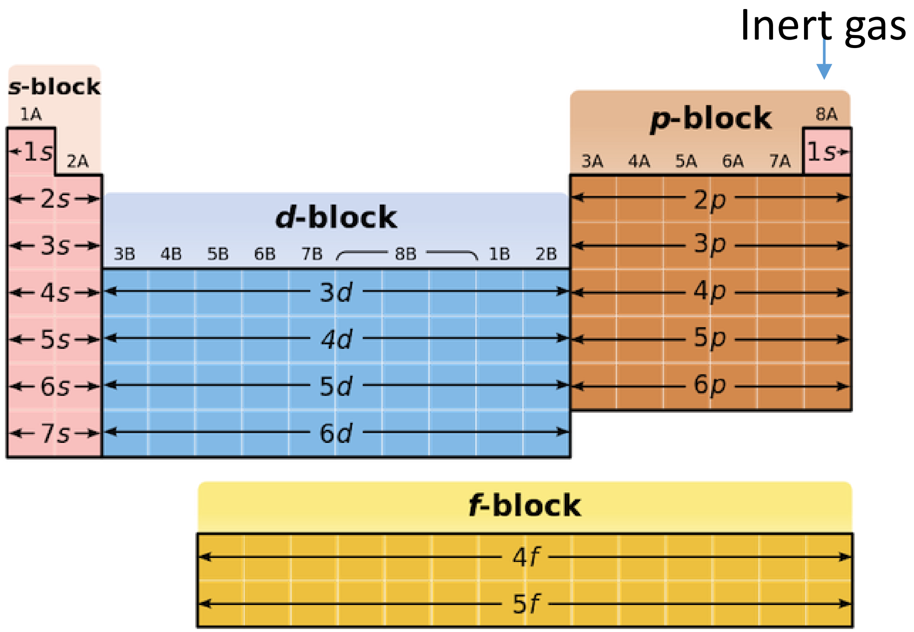
Examples of different non-traditional forms of the periodic chart for the elements:
(a) the spiral form due to Baumgauer,
(b) the helical form due to Bilecki and
(c) the 'dumb-bell' form due to Basset

Classification of the elements based on electronic configuration and chemical affinities

s-block; p-block; d-block; f-block

3d-series
4d-series
5d-series

4f-block
5f-block



Advantages??

Disadvantages??

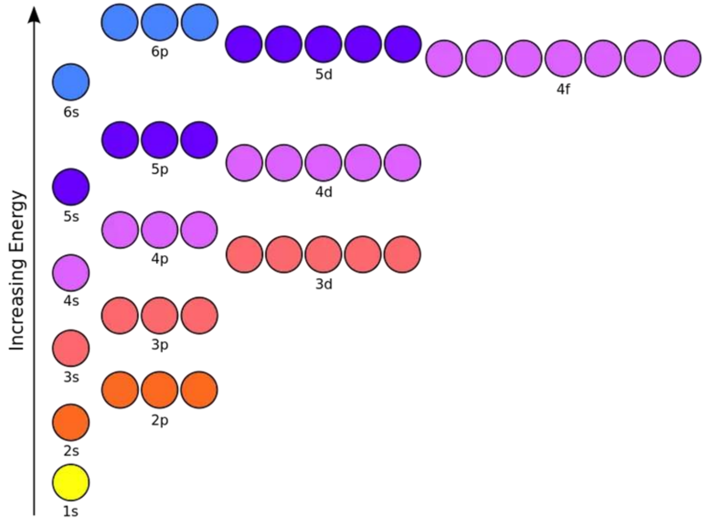
Bohr's classification:

i) Inert gas;

ii) representative or normal elements;

iii) Transition elements;

iv) Inner transition elements



Goldschimdt's geochemical classification of elements based on chemical affinity:

Distribution of different elements in crust, mantle and core of the earth is governed by their chemical affinities.

a) Siderophores: Iron loving elements..Tend to be associated with iron.. Triads of group VIII

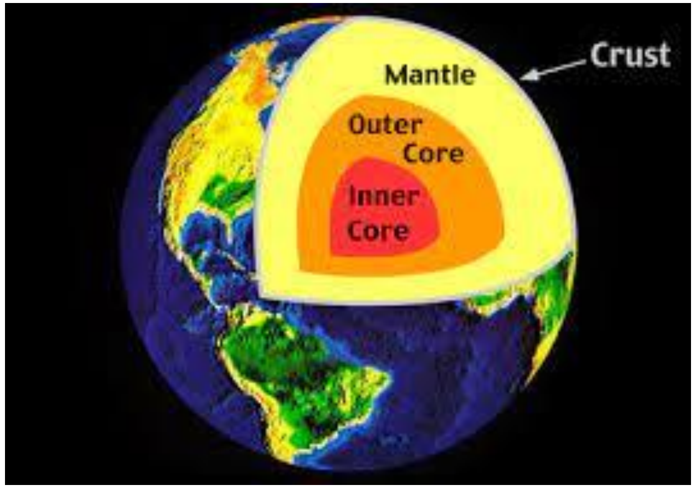
b) Chalcophiles: Sulphide loving elements..Their ions are soft acids, according to HSAB theory..
Possess 18 electrons in the outer shell.. Cu, Zn, Cd, Hg, Pb, As, Sb

c) Lithophiles: stone loving elements..These metal ions are tend to be associated with oxides. These ions are typically hard acids. Possess 8 electrons in the outer shell. Alkali metals, alkaline earth metals and early member of transition metals

d) Atmophiles: Vapor loving elements..Such elements tend to remain in gaseous form.. N, O, inert gases

Cr is lithophilic in crust, but in oxygen deficient condition, it can be Chalcophile.

Fe is siderophilic in the core, but lithophilic in crust.



Classification of Zn, Cd, Hg?? d^{10} elements

Lu, Th, Lr ?? Transition or inner-transition?

Position of lighter actinides? Case of Th, Pa, U

5f and 6d are close to energy

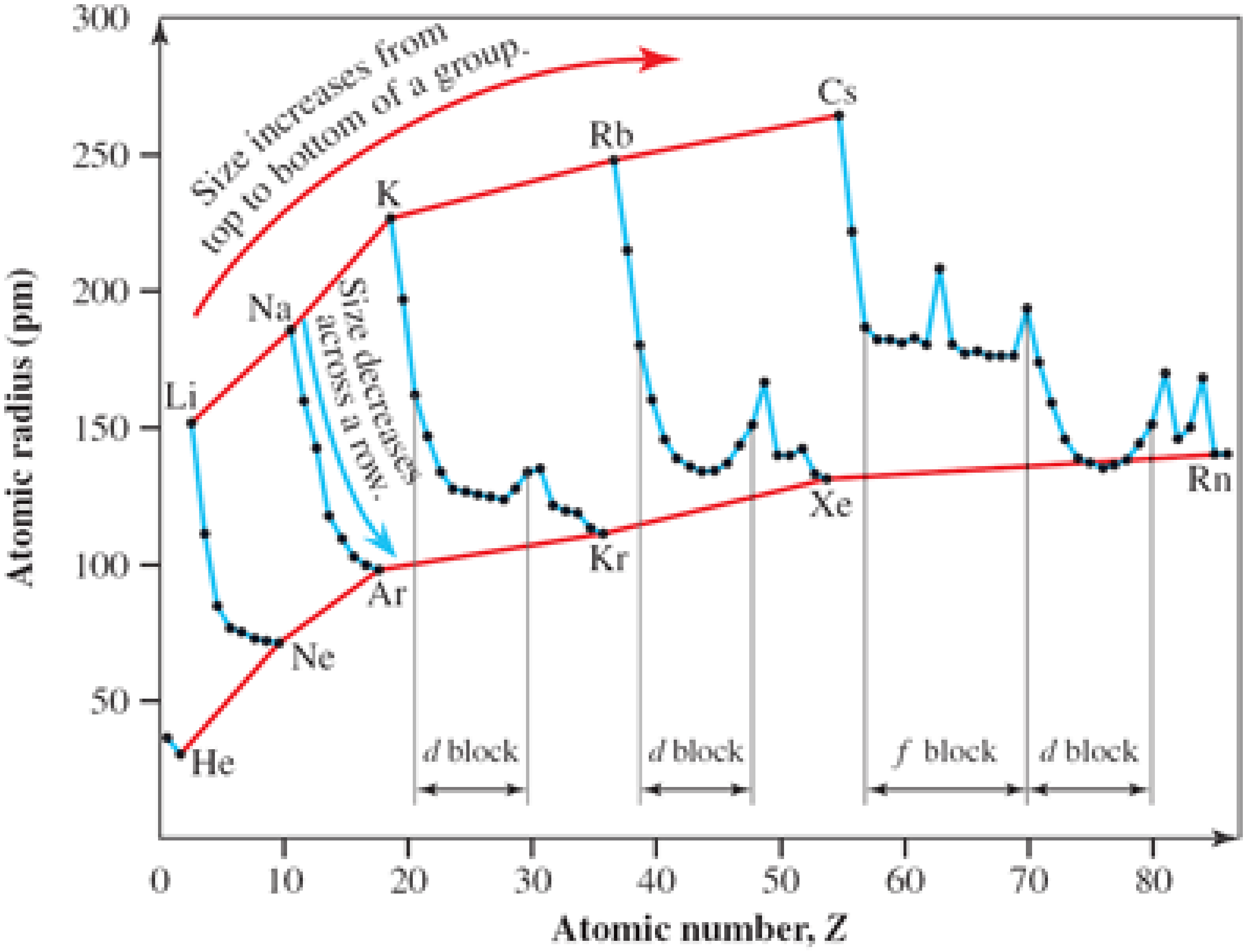
Th, Pa, U placed in Gr. 4, 5 and 6, respectively by mistake as d-block element..

Seaborg corrected this and proposed this elements to be a member of new inner transition metal series.

As usual, Seaborg was criticized for this new hypothesis and warned not to publish this actinide hypothesis because it Would destroy his scientific career. He then said humorously- “I did not have any scientific reputation so I published this anyway.”

This actinide hypothesis saved chemistry.

Periodic trends of atomic size or radius:



Why ?

Effective nuclear charge:

$Z^* = Z$ – screening const (S)

It is experienced by the outer most electron and the value of the principal quantum number (n) are important to determine The periodic trends of the sizes.

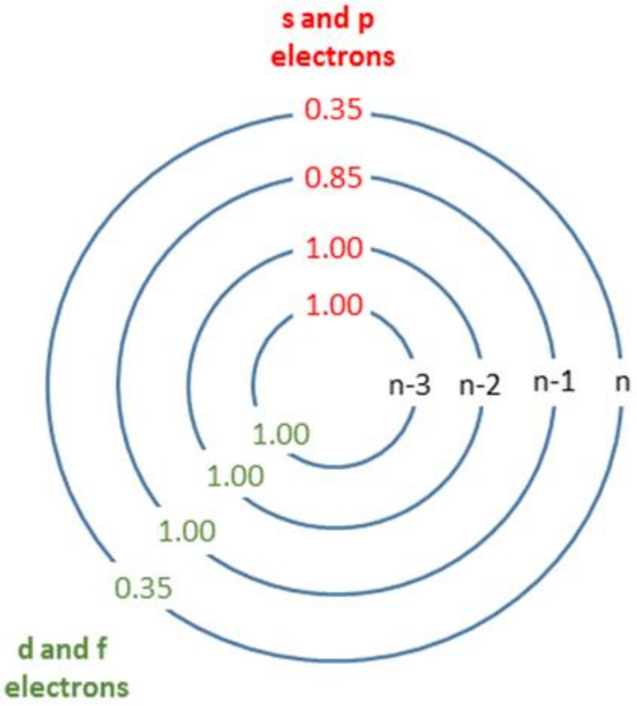
$\langle r_{max} \rangle \sim a_0 (n^*)^2/Z^*$…. a_0 = 53 pm (Bohr radius of H-atom)
n^* = effective principal quantum number for the valence shell electron
Z^* = effective nuclear charge, can be obtained by Slater's rule

s and p-block element : $Z^* = 0.65 + 0.65n$ (n= no. of valence electron)
d- block element : $Z^* = 2.85 + 0.15n$ (n = no. of electrons in the (n-1)d orbital

For example: Al^{13} $\underbrace{1s^2}_{(n-2)}$ $\underbrace{2s^2\ 2p^6}_{(n-1)}$ $\underbrace{3s^2\ 3p^1}_{n}$

Group	no. of electrons	Contribution of each electron to 'S' value	Contribution of a particular group
n	2	0.35	0.70
(n – 1)	8	0.85	6.80
(n – 2)	2	1	2.00
			9.50

$Z^* = Z - S$



The greater the effective nuclear charge, the more strongly the outermost electrons are attracted to the nucleus and the smaller the atomic radius.

Q. Using Slater's rule calculate the effective nuclear charge on a 3p electron in aluminium and chlorine. Explain how these results relate to the atomic radii of the two atoms.

Slater's Rules

- **Step 1**: Write the electron configuration of the atom in the following form:

  (1s) (2s, 2p) (3s, 3p) (3d) (4s, 4p) (4d) (4f) (5s, 5p) . . .

- **Step 2**: Identify the electron of interest, and ignore all electrons in higher groups (to the right in the list from Step 1). These do not shield electrons in lower groups
- **Step 3**: Slater's Rules is now broken into two cases:
  - the shielding experienced by an s- or p- electron,
    - electrons within same group shield **0.35**, except the 1*s* which shield **0.30**
    - electrons within the n-1 group shield **0.85**
    - electrons within the n-2 or lower groups shield **1.00**
  - the shielding experienced by n*d* or n*f* valence electrons
    - electrons within same group shield **0.35**
    - electrons within the lower groups shield **1.00**

Q. Calculate the Shielding of 3d Electrons of Bromine Atoms ?

Effective Nuclear Charges

	H	He
Z	1	2
1s	1.000	1.688

	Li	Be	B	C	N	O	F	Ne
Z	3	4	5	6	7	8	9	10
1s	2.691	3.685	4.680	5.673	6.665	7.658	8.650	9.642
2s	1.279	1.912	2.576	3.217	3.847	4.492	5.128	5.758
2p			2.421	3.136	3.834	4.453	5.100	5.758

	Na	Mg	Al	Si	P	S	Cl	Ar
Z	11	12	13	14	15	16	17	18
1s	10.626	11.609	12.591	13.575	14.558	15.541	16.524	17.508
2s	6.571	7.392	8.214	9.020	9.825	10.629	11.430	12.230
2p	6.802	7.826	8.963	9.945	10.961	11.977	12.993	14.008
3s	2.507	3.308	4.117	4.903	5.642	6.367	7.068	7.757
3p			4.066	4.285	4.886	5.482	6.116	6.764

	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Z	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1s	18.490	19.473	20.457	21.441	22.426	23.414	24.396	25.381	26.367	27.353	28.339	29.325	30.309	31.294	32.278	33.262	34.247	35.232
2s	13.006	13.776	14.574	15.377	16.181	16.984	17.794	18.599	19.405	20.213	21.020	21.828	22.599	23.365	24.127	24.888	25.643	26.398
2p	15.027	16.041	17.055	18.065	19.073	20.075	21.084	22.089	23.092	24.095	25.097	26.098	27.091	28.082	29.074	30.065	31.056	32.047
3s	8.680	9.602	10.340	11.033	11.709	12.368	13.018	13.676	14.322	14.961	15.594	16.219	16.996	17.790	18.596	19.403	20.219	21.033
3p	7.726	8.658	9.406	10.104	10.785	11.466	12.109	12.778	13.435	14.085	14.731	15.369	16.204	17.014	17.850	18.705	19.571	20.434
4s	3.495	4.398	4.632	4.817	4.981	5.133	5.283	5.434	5.576	5.711	5.842	5.965	7.067	8.044	8.944	9.758	10.553	11.316
3d			7.120	8.141	8.983	9.757	10.528	11.180	11.855	12.530	13.201	13.878	15.093	16.251	17.378	18.477	19.559	20.626
4p													6.222	6.780	7.449	8.287	9.028	9.338

	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Z	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
1s	36.208	37.191	38.176	39.159	40.142	41.126	42.109	43.092	44.076	45.059	46.042	47.026	48.010	48.992	49.974	50.957	51.939	52.922
2s	27.157	27.902	28.622	29.374	30.125	30.877	31.628	32.380	33.155	33.883	34.634	35.386	36.124	36.859	37.595	38.331	39.067	39.803
2p	33.039	34.030	35.003	35.993	36.982	37.972	38.941	39.951	40.940	41.930	42.919	43.909	44.898	45.885	46.873	47.860	48.847	49.835
3s	21.843	22.664	23.552	24.362	25.172	25.982	26.792	27.601	28.439	29.221	30.031	30.841	31.631	32.420	33.209	33.998	34.787	35.576
3p	21.303	22.168	23.093	23.846	24.616	25.474	26.384	27.221	28.154	29.020	29.809	30.692	31.521	32.353	33.184	34.009	34.841	35.668
4s	12.388	13.444	14.264	14.902	15.283	16.096	17.198	17.656	18.582	18.986	19.865	20.869	21.761	22.658	23.544	24.408	25.297	26.173
3d	21.679	22.726	25.397	25.567	26.247	27.228	28.353	29.359	30.405	31.451	32.540	33.607	34.678	35.742	36.800	37.839	38.901	39.947
4p	10.881	11.932	12.746	13.460	14.084	14.977	15.811	16.435	17.140	17.723	18.562	19.411	20.369	21.265	22.181	23.122	24.030	24.957
5s	4.985	6.071	6.256	6.446	5.921	6.106	7.227	6.485	6.640	(empty)	6.756	8.192	9.512	10.629	11.617	12.538	13.404	14.218
4d			15.958	13.072	11.238	11.392	12.882	12.813	13.442	13.618	14.763	15.877	16.942	17.970	18.974	19.960	20.934	21.893
5p													8.470	9.102	9.995	10.809	11.612	12.425

https://en.wikipedia.org/wiki/Effective_nuclear_charge

Table 8.10.2.1. Variation of Z^* (calculated by Slater's rule) for the valence electron

	s-block		p-block					
	IA (1)	IIA (2)	IIIA (13)	IVA (14)	VA (15)	VIA (16)	VIIA (17)	VIIIA (18)
Period 2	Li 1.30	Be 1.95	B 2.60	C 3.25	N 3.90	O 4.55	F 5.20	Ne 5.85
Period 3	Na 2.20	Mg 2.85	Al 3.50	Si 4.15	P 4.80	S 5.45	Cl 6.10	Ar 6.75
Period 4	K 2.20	Ca 2.85	Ga 5.00	Ge 5.65	As 6.30	Se 6.95	Br 7.60	Kr 8.25

Scandide contraction: d-contraction

Ca ⟶ Ga (2.15 unit change in Z*)

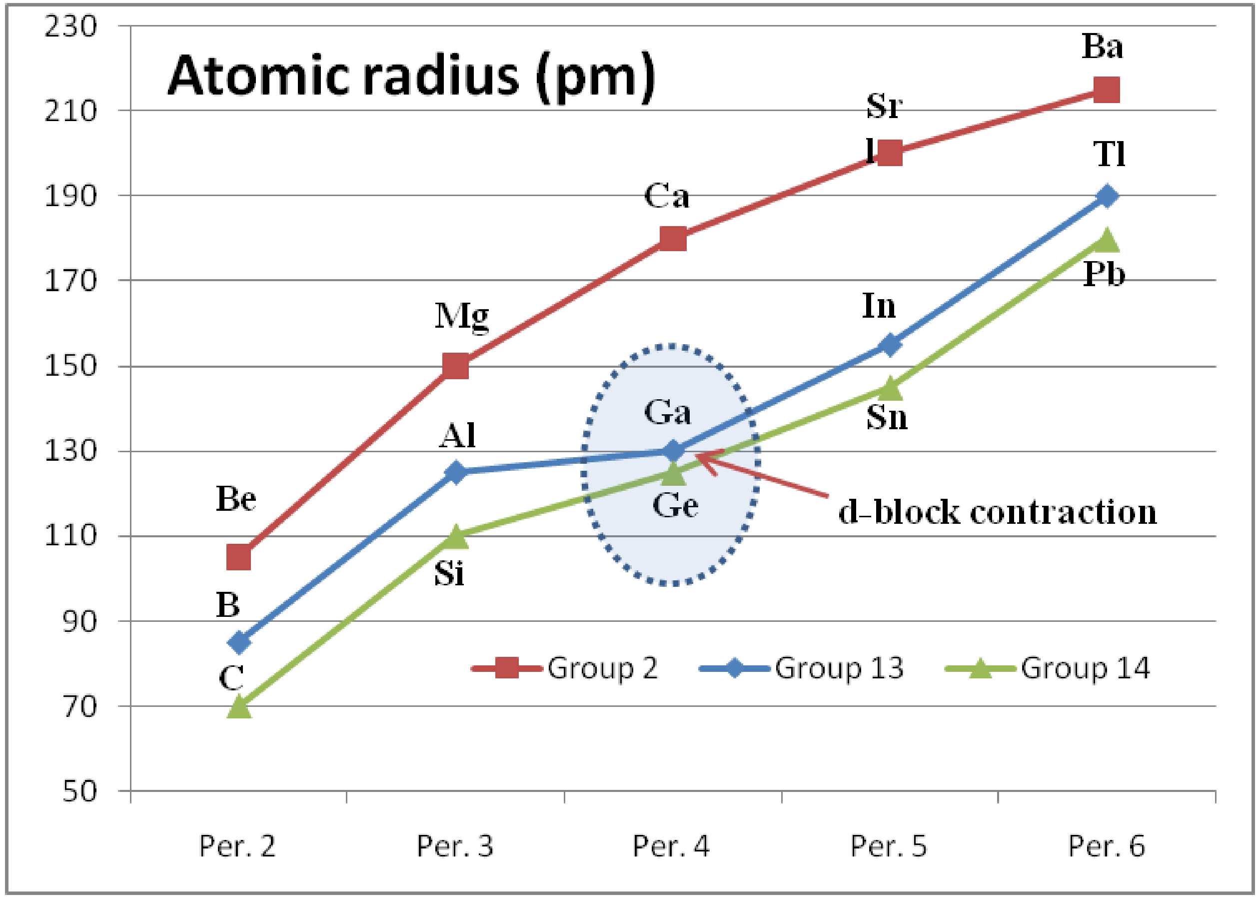
So, the main reason of the d-block contraction is the poor shielding of the nuclear charge by the electrons in the d orbitals.

This d-block contraction may be compared to the Lanthanide Contraction which is also caused by the inadequate shielding of the nuclear charge by the electrons occupying f orbitals.

Scandide contraction

The d-block Contraction is also known as the Scandide Contraction.

The effect of the d- block contraction occurs on the period 4 elements due to the full d orbitals. This contraction thing affects the elements Gallium (Ga), Germanium (Ge), Arsenic (As), Selenium (Se), Bromine (Br), and Krypton (Kr) mainly.

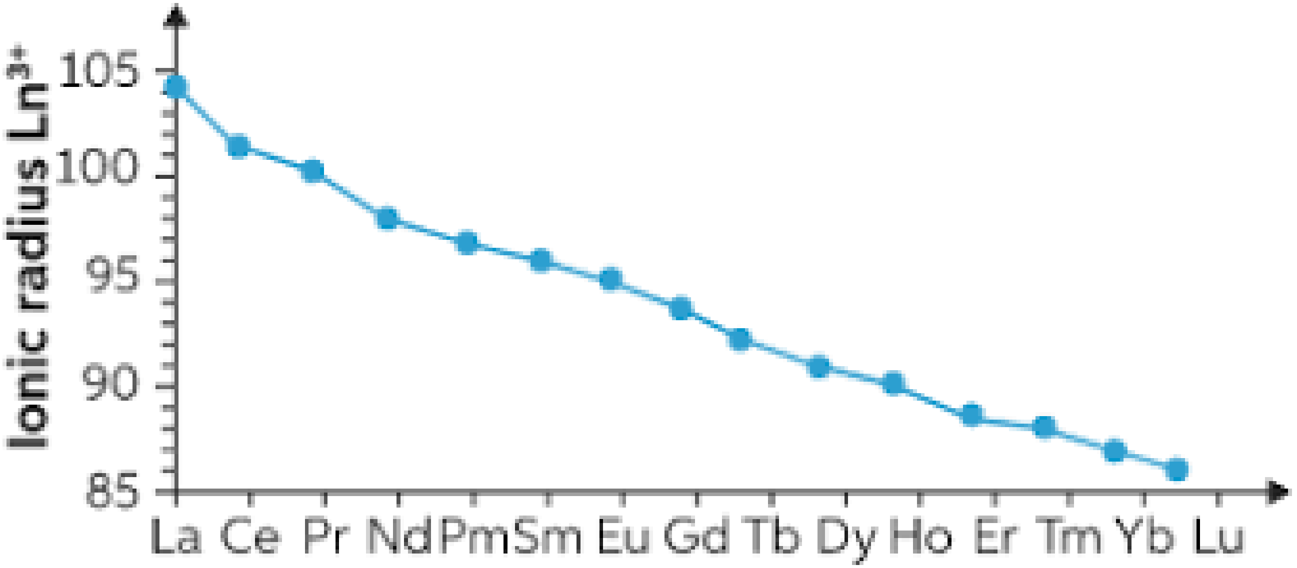


Lanthanide contraction

Lanthanide contraction is the decrease in the size of atoms with the increasing atomic number in the lanthanide series.

It is a steady decrease in the atomic radius and the ionic radius of chemical elements in the lanthanide series. Further, this happens because of the filling of 4f orbitals with electrons before filling up the 5d orbital. Here, the 4f electrons show a poor shielding towards the nuclear charge, which in turn cause the 6s electrons to move towards the nucleus of the atom, resulting in a small radius.

•The shielding effect of 4f is very smaller than d orbital as 4f Orbital is much diffuse in nature.



- The elements in which the additional electrons enters (n-2)f orbitals are called inner transition elements. The valence shell electronic configuration of these elements can be represented as $(n-2)f^{0\text{-}14}(n-1)d^{0\text{-}1}ns^2$.
- 4f inner transition metals are known as lanthanides because they come immediately after lanthanum and 5f inner transition metals are known as actinoids because they come immediately after actinium.

La (57)

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6\ 5d^1\ 6s^2$

[Xe] – 54

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6\ 4d^{10}\ 5s^2\ 5p^6$

The electronic configuration of Ln is

[Xe] $4f^0\ 5d^1\ 6s^2$ or [Xe] $4f^0$

Element name	Symbol	Z	Ln	Ln^{3+}
Lanthanum	La	57	$[Xe]6s^2 5d^1$	$[Xe]4f^0$
Cerium	Ce	58	$[Xe]4f^1 6s^2 5d^1$	$[Xe]4f^1$
Praesodymium	Pr	59	$[Xe]4f^3 6s^2$	$[Xe]4f^2$
Neodymium	Nd	60	$[Xe]4f^4 6s^2$	$[Xe]4f^3$
Promethium	Pm	61	$[Xe]4f^5 6s^2$	$[Xe]4f^4$
Samarium	Sm	62	$[Xe]4f^6 6s^2$	$[Xe]4f^5$
Europium	Eu	63	$[Xe]4f^7 6s^2$	$[Xe]4f^6$
Gadolinium	Eu	64	$[Xe]4f^7 6s^2 5d^1$	$[Xe]4f^7$
Terbium	Tb	65	$[Xe]\ 4f^9 6s^2$	$[Xe]4f^8$
Dysprosium	Dy	66	$[Xe]\ 4f^{10} 6s^2$	$[Xe]4f^9$
Holmium	Ho	67	$[Xe]\ 4f^{11} 6s^2$	$[Xe]4f^{10}$
Erbium	Er	68	$[Xe]\ 4f^{12} 6s^2$	$[Xe]4f^{11}$
Thulium	Tm	69	$[Xe]\ 4f^{13} 6s^2$	$[Xe]4f^{12}$
Ytterbium	Yb	70	$[Xe]\ 4f^{14} 6s^2$	$[Xe]4f^{13}$
Lutetium	Lu	71	$[Xe]\ 4f^{14} 6s^2 5d^1$	$[Xe]4f^{14}$

Any f orbital containing 1 electron is unstable. So it transfers the electron to 5d and due to this the energy of 5d decreases and it becomes stable. Now when an another electron comes it is then added to 4f (cerium)

II Post Lanthanides –

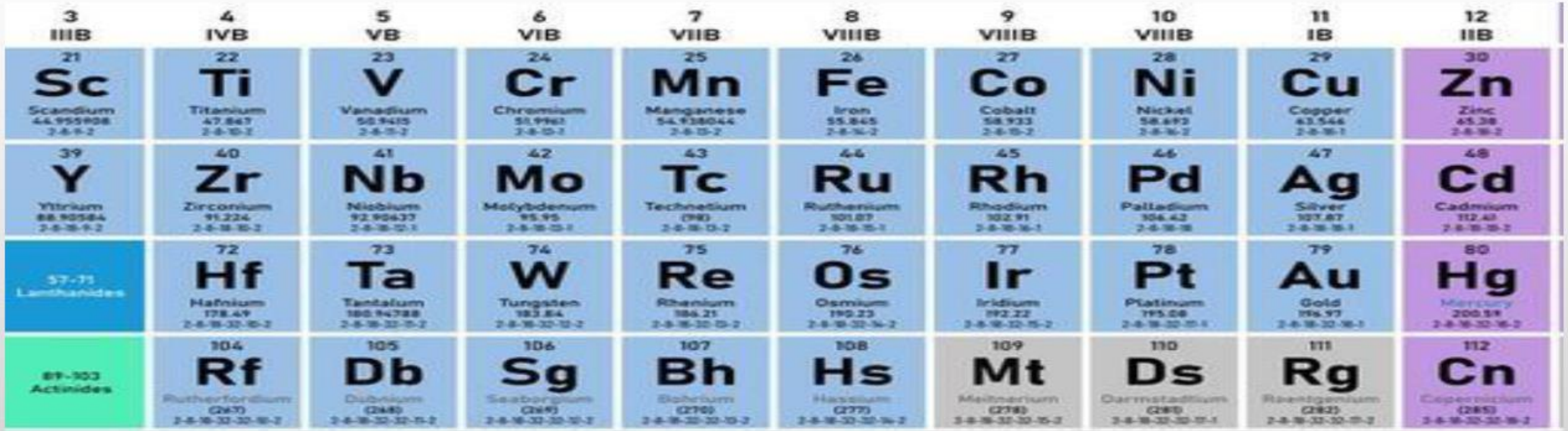
i) **Occurrence of elements as pairs** – Due to similar size of 4d and 5d in a group, they have similar physical and chemical properties, they occur together in nature and their separation becomes very difficult.

Zr/Hf, Nb/Ta, Mo/W

ii) **Densities** – 5d elements have very high densities as down the group there is large increase in mass but no increase in volume.

III Occurrence of Yttrium along with heavier lanthanides –

yttrium has similar charge and size to Ho^{3+} & Er^{3+} hence it occurs with and separation is difficult.



There is normal increase in size Sc to Y to La.

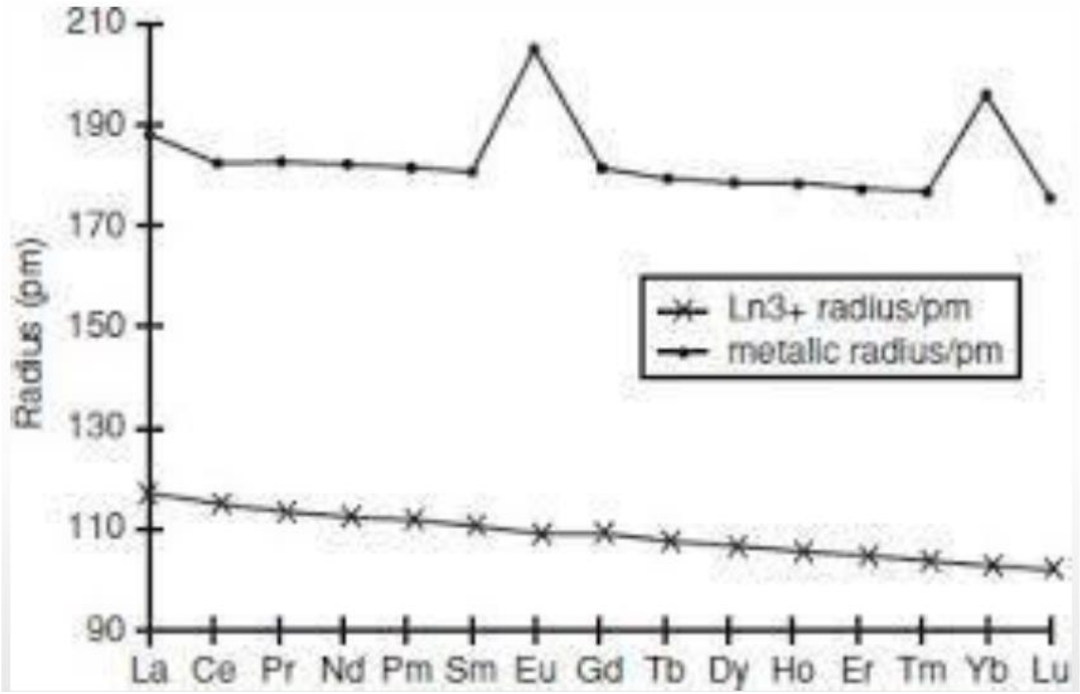
There is an appreciable increase in the atomic radii of europium and ytterbium in comparison to the preceding elements while no increase is observed for the corresponding trivalent ions.

The size increase in the ease of the free metals is attributed to the presence of dipositive ions giving only two valence electrons for metallic bonding instead of the three usually encountered for lanthanide metals.

The structures of these two metals also differ from the hexagonal, closely packed structure encountered for most of the lanthanide metals.

Europium and ytterbium might be expected to give only two valence electrons because of the stability of half-filled and filled/orbitals which would be achieved in these instances.

Compounds of europium(II) and ytterbium(II) are well characterized.



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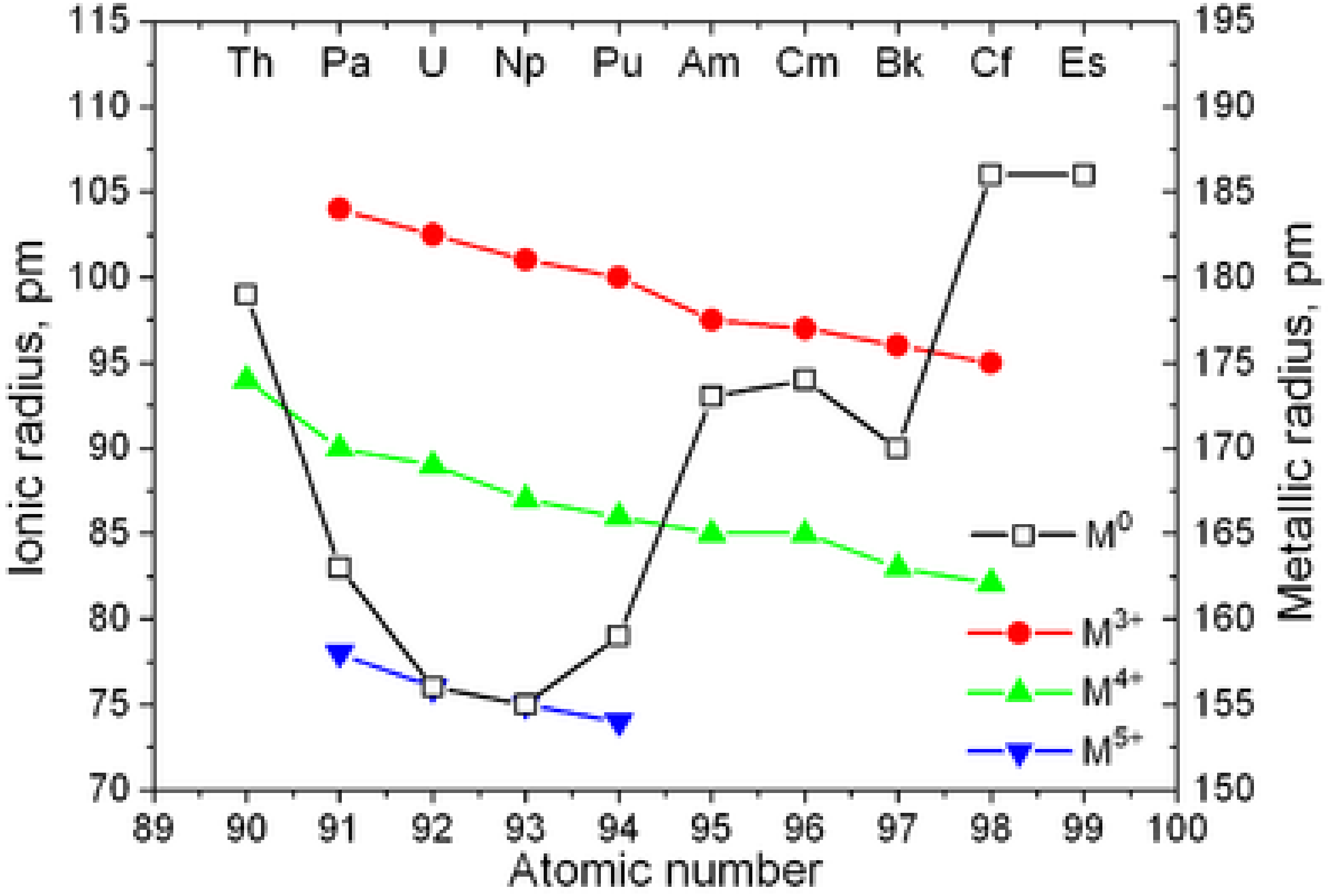
Actinide contraction

- The contraction is caused due to imperfect shielding of one 5f electron by another in the same shell.
- As we move along the actinide series, the nuclear charge and the number of 5f electrons increase one unit by each step.
- Due to imperfect shielding (shape of f orbitals are very much diffused) the effective nuclear charge increases which causes contraction in the size of electron cloud.
- In actinides contraction there are bigger jumps in contraction between the consecutive elements as compared to lanthanides.
- Lesser shielding of 5f electrons compared to 4f electrons.

Actinide contraction



Z	Name	Symbol	Electronic configuration outside the [Xe] core An	An^{3+}	Metallic radius (pm)	Ionic radius M^{3+} (pm)
89	Actinium	Ac	$6d^17s^2$	$5f^0$	-	112
90	Thorium	Tc	$6d^27s^2$	$5f^1$	179	-
91	Protactinium	Pa	$5f^26d^17s^2$	$5f^2$	163	104
92	Uranium	U	$5f^36d^17s^2$	$5f^3$	156	103
93	Neptunium	Np	$5f^46d^17s^2$	$5f^4$	155	101
94	Plutonium	Pu	$5f^67s^2$	$5f^5$	155	100
95	Americium	Am	$5f^77s^2$	$5f^6$	159	98
96	Curium	Cm	$5f^76d^17s^2$	$5f^7$	173	97
97	Berkelium	Bk	$5f^97s^2$	$5f^8$	174	96
99	Californium	Cf	$5f^{10}7s^2$	$5f^9$	170	95
98	Einstenium	Es	$5f^{11}7s^2$	$5f^{10}$	186 ± 2	-
100	Fermium	Fm	$5f^{12}7s^2$	$5f^{11}$	186 ± 2	-
101	Mendelevium	Md	$5f^{13}7s^2$	$5f^{12}$	-	-
102	Nobelium	No	$5f^{14}7s^2$	$5f^{13}$	-	-
103	Lawrencium	Lr	$5f^{14}6d^17s^2$	$5f^{14}$	-	-

Oxidation state

Name	Oxidation states
Actinium	+3
Thorium	+3, +4
Protactinium	+3, +4, +5
Uranium	+3, +4, +5, +6
Neptunium	+3, +4, +5, +6, +7
Plutonium	+3, +4, +5, +6, +7
Americium	+2, +3, +4, +5, +6
Curium	+3, +4
Berkelium	+3, +4
Californium	+2, +3
Einstenium	+2, +3
Fermium	+2, +3
Mendelevium	+2, +3
Nobelium	+2, +3
Lawrencium	+3

Ionic Radii of ions show a clear "Actinide Contraction"

- Actinide 3+ or 4+ ions with similar radii to their Lanthanide counterparts show similarities in properties that depend upon ionic radius