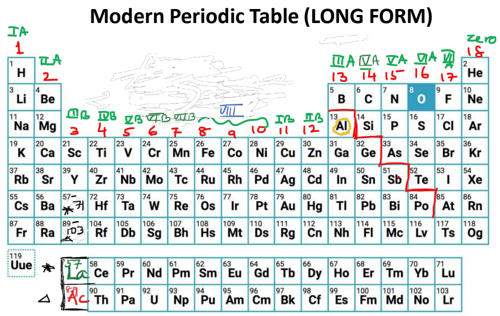
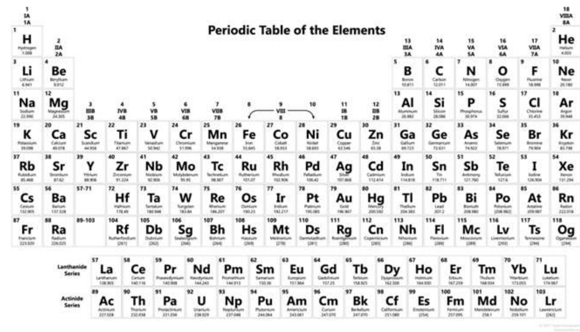




National Periodic Table Day

7th February 2025

Long Form of Periodic Table

- Groups : 18
- Periods: 7
- Left Portion: Gr.1 and 2 (two groups) s-block
- Right Portion : Gr. 13 to 18 (six groups) p-block
- Middle Portion : Transition Metals: Gr. 3 – 12 (d-block)
- Bottom Portion : Lanthanoids and Actinoids (Group 3) f-block

S-Block Elments(Left Portion)

- Group 1 (IA) : Alkali Metals:

  Li(3), Na(11), K(19), Rb(37), Cs(55), Fr*(87) :

  Valence EC : ns^1 (n = 2 – 7)
- Group 2(IIA): Alkaline Earth Metals:

  Be(4), Mg(12), Ca(20), Sr(38), Ba(56), Ra*(88):

  Valence EC : ns^2(n=2-7)

Magic Numbers: 8, 8, 18, 18, 32 (exclude 1st Period)

Why the name Alkali and Alkaline Earth Metals?

- Alkali metals are called such because when they react with water, they form alkaline solutions, known as "alkalies", while alkaline earth metals are named so because their oxides, which were historically called "earths", are also alkaline when combined with water; essentially, both names reflect their basic (alkaline) nature when reacting with water.

P-Block Elements(Right Portion)

- Group 13(IIIA) : B-Family
  B(5), Al(13), Ga(31), In(49), Tl(81), Nh*(113)
  Valence EC : ns^2, np^1 (n = 2 – 7)
- Group 14(IVA) : C- Family
  C(6), Si(14), Ge(32), Sn(50), Pb(82), Fl*(114)
  Valence EC : ns^2, np^2 (n = 2 – 7)
- Group 15(VA) : N – Family (Pnicogens)
  N(7), P(15), As(33), Sb(51), Bi(83), Mc*(115)
  Valence EC : ns^2, np^3 (n = 2 – 7)

P-Block (Contd.)

- Group 16(VIA) : O- Family (Chalcogens)
  O(8), S(16), Se(34), Te(52), Po*(84), Lv*(116)
  Valence EC : ns^2, np^4 (n = 2 – 7)
- Group 17(VIIA) : Halogens
  F(9), Cl(17), Br(35), I(53), At*(85), Ts*(117)
  Valence EC : ns^2, np^5 (n = 2 – 7)
- Group 18(Zero) : Noble Gases
  He(2),Ne(10),Ar(18), Kr(36), Xe(54), Rn*(86),Og*(118)
  Valence EC : ns^2, np^6 (Exception: He: $1s^2$)
  Stable Octet and Duplet configuration
- Magic Numbers(Exclude 1st Period) : 8, 18, 18, 32, 32

Why the names Pnicogens, Chalcogens and Halogens?

- Pnicogens" are named from the Greek word "pnigein" meaning "to choke", referring to the choking property of nitrogen gas, the most prominent element in that group; "Chalcogens" come from the Greek word “khalkos” meaning "copper" because many copper ores contain elements from this group like sulfur and selenium; and "Halogens" derive from Greek "halos" meaning "salt" and "gen” meaning “producer”, as these elements readily form form salts with metals.

Normal or Representative Elements and Transition Metals

- s- and p-block elements together called Representative or Normal Elements.
- Transition Elements- d block
- Inner Transition – f-block

D-Block Elements(Transition Elements)

- Group 3(IIIB) : Sc Family
  Sc(21), Y(39), La(57) (+ 14 Ln elements: Ce-Lu)
  Ac(89)(+14 An elements: Th-Lr)
  EC:[Noble Gas] $(n-1)d^1$, ns^2 (n = 4-7)
- Group 4(IVB) : Ti Family
  Ti(22), Zr(40), Hf(72), Rf*(104)
  EC :[Noble Gas] $(n-1)d^2$, ns^2 For Ti, Zr(n=4,5)
  $(n-2)f^{14}$, $(n-1)d^2$, ns^2 For Hf, Rf (n=6,7)

D-Block(contd.)

- Group 5(VB) : V – Family
  V(23), Nb(41), Ta(73), Db*(105)
  EC : V : [Ar], $3d^3$, $4s^2$; Nb : [Kr], $4d^4$, $5s^1$;
  Ta: [Xe], $4f^{14}$, $5d^3$, $6s^2$ Db: [Rn], $5f^{14}$, $6d^3$, $7s^2$
- Group 6(VIB) : Cr- Family
  Cr(24), Mo(42), W(74), Sg*(106)
  EC: Cr : [Ar], $3d^5$, $4s^1$; Mo : [Kr], $4d^5$, $5s^1$;
  W : [Xe], $4f^{14}$, $5d^4$, $6s^2$ Sg: [Rn], $5f^{14}$, $6d^4$, $7s^2$

D-Block(contd.)

- Group 7(VIIB) : Mn Group
  Mn(25), Tc*(43), Re(75), Bh*(107)
  EC: Mn : [Ar], $3d^5$, $4s^2$; Tc : [Kr], $4d^5$, $5s^2$;
  Re : [Xe], $4f^{14}$, $5d^5$, $6s^2$ Bh: [Rn], $5f^{14}$, $6d^5$, $7s^2$
- Group 8(VIII: first column) : Fe Group
  Fe(26), Ru(44), Os(76), Hs*(108)
  EC: Fe : [Ar], $3d^6$, $4s^2$; Ru : [Kr], $4d^7$, $5s^1$;
  Os : [Xe], $4f^{14}$, $5d^6$, $6s^2$ Hs: [Rn], $5f^{14}$, $6d^6$, $7s^2$

D-Block(contd.)

- Group 9 (VIII – 2^{nd} column) : Co group
  Co(27), Rh(45), Ir(77), Mt*(109)
  EC: Co : [Ar], $3d^7$, $4s^2$; Rh : [Kr], $4d^8$, $5s^1$;
  Ir : [Xe], $4f^{14}$, $5d^7$, $6s^2$ Mt: [Rn], $5f^{14}$, $6d^7$, $7s^2$
- Group 10 (VIII – 3^{rd} Column) : Ni group
  Ni(28), Pd(46), Pt(78), Ds*(110)
  EC: Ni : [Ar], $3d^8$, $4s^2$; Pd : [Kr], $4d^{10}$, $5s^0$;
  Pt : [Xe], $4f^{14}$, $5d^9$, $6s^1$ Ds: [Rn], $5f^{14}$, $6d^8$, $7s^2$

D-Block(contd.)

- Group 11 (IB) : Cu group (Coinage Metals)
- Cu(29), Ag(47), Au(79), Rg*(111)
  EC: Cu : [Ar], $3d^{10}$, $4s^1$; Ag : [Kr], $4d^{10}$, $5s^1$;
  Au : [Xe], $4f^{14}$, $5d^{10}$, $6s^1$ Rg: [Rn], $5f^{14}$, $6d^9$, $7s^2$

* Group 12 (IIB) : Zn group
  Zn(30), Cd(48), Hg(80), Cn*(112)
  EC: Zn : [Ar], $3d^{10}$, $4s^2$; Cd : [Kr], $4d^{10}$, $5s^2$;
  Hg : [Xe], $4f^{14}$, $5d^{10}$, $6s^2$ Rg: [Rn], $5f^{14}$, $6d^{10}$, $7s^2$

D-Block: The differentiating electron enters to a d-orbital.

F-Block Elements(Inner Transition Elements)

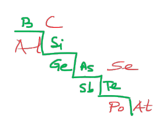
- Lanthanides/Lanthanoids/Lanthanones(Rare Earths/REE) :
- Ln (15 elements)
  La(57) ; Ce(58), Pr(59), Nd(60), Pm*(61), Sm(62), Eu(63), Gd(64), Tb(65), Dy(66), Ho(67), Er(68), Tm(69), Yb(70), Lu(71)
  EC: Ln : [Xe] $4f^{0-14}$, $5d^{0-1}$, $6s^2$,
  La(57): [Xe]$6s^2$ $5d^1$ Ce(58): [Xe] $6s^2$ $5d^1$ $4f^1$
  Gd(64): [Xe] $6s^2$, $5d^1$, $4f^7$

Others obey Aufbau order.
The differentiating electron enters into a f-orbital.

F-Block(contd.)

- Actinides/Actinoids/Actinones : 15 elements
  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)
- Anomalous EC: (7)
  Ac(89): [Rn]$7s^2$ $6d^1$ Th(90): [Rn]$7s^2$ $6d^2$
  Pa(91) :[Rn]$7s^2$ $6d^1$ $5f^2$ U(92) :[Rn]$7s^2$ $6d^1$ $5f^3$
  Np(93): [Rn]$7s^2$ $6d^1$ $5f^4$ Cm(96):[Rn]$7s^2$ $6d^1$ $5f^7$
  Lr(103): [Rn]$7s^2$ $5f^{14}$, $7p^1$
- Others follow Aufbau order

Stair-steps separating Metals from Non-metals



- Stair-steps running below B
- Left of stair steps : Metals
- Right of Stair steps : Non-metals
- In the immediate vicinity: Metalloids(Semi-metals)
- Metalloids: B, Si, Ge, As, Sb, Te
- Five other 2^{nd} Grade Metalloids: C, Al, Se, Po, At

Determination of Atomic Numbers(Z) from Magic Numbers

- s-block: 8, 8, 18, 18, 32 (Exclude 1st period)
- p-block: 8, 18, 18, 32, 32 (Exlude 1st period)
- Then connect d-series horizontally
- 5d- series : After La(57), assign to other Ln elements from Ce(58) to Lu(71), then return to Hf(72) onwards.
- 6d-series: After Ac(89), assign to other An elements from Th(90) to Lr(103), then return to Rf(104) onwards.

Natural and Synthetic Elements

- Natural: 94 : Upto 94(Pu)
- Purely Synthetic: ≥ 95 (Americium onwards)(95-118). These are commonly called Transuranic elements.
- **Both Natural and Synthetic:** Tc(43), Pm(61), Po(84), At(85), Fr(87), Ra(88), Ac(89), Pa(91), Np(93), Pu(94) = 10 elements
- Total Synthetic Elements: 24+10 = 34

Radioactive Elements

- Natural: Above Z=83(Bi) upto Pu(94) (Bi=stable)
  Po(84) onwards upto Pu(94)
- Synthetic: Am(95) onwards …….
- Tc(43) : Now synthetic
- Pm(61) : Now synthetic
- Some lighter elements also have natural radioactive isotopes eg H-3, K-40, C-14 etc.
- Do you know, Bi-209 is now considered to be radioactive with half life period of 1.9×10^{19} years.

Symbols with Names of Elements (Group-wise)

Group 1	Group 2	Group 3	Group 4
H : Hydrogen(1)			
Li : Lithium(3)	Be : Beryllium(4)		
Na : Sodium(11)	Mg: Magnesium(12)		
K : Potassium(19)	Ca : Calcium(20)	Sc : Scandium(21)	Ti : Titanium(22)
Rb: Rubidium(37)	Sr : Strontium(38)	Y : Yttrium(39)	Zr : Zirconium(40)
Cs: Caesium(55)	Ba : Barium(56)	La : Lanthanum(57)	Hf : Hafinium(72)
Fr: Francium(87)	Ra: Radium(88)	Ac : Actinium(89)	Rf :Rutherfordium(104)

Group 5	Group 6	Group 7	Group 8
V : Vanadium(23)	Cr : Chromium(24)	Mn : Manganese(25)	Fe : Iron(26)
Nb : Niobium(41)	Mo : Molybdenum(42)	Tc : Technetium(43)	Ru :Ruthenium(44)
Ta : Tantalum(73)	W : Tungsten(74)	Re : Rhenium(75)	Os : Osmium(76)
Db: Dubnium(105)	Sg : Seaborgium(106)	Bh : Bohrium(107)	Hs: Hassium(108)

Symbols with Names of Elements (Group-wise)

Group 9	Group 10	Group 11	Group 12
Co : Cobalt(27)	Ni : Nickel(28)	Cu : Copper(29)	Zn : Zinc(30)
Rh : Rhodium(45)	Pd : Palladium(46)	Ag : Silver(47)	Cd : Cadmium(48)
Ir : Iridium(77)	Pt : Platinum(78)	Au : Gold (79)	Hg : Mercury(80)
Mt : Meitnerium(109)	Ds: Darmstadtium(110)	Rg : Roentgenium(111)	Cn: Copernicium(112)

Group 13	Group 14	Group 15	Group 16
B : Boron(5)	C : Carbon(6)	N : Nitrogen(7)	O : Oxyge(8)
Al : Aluminium(13)	Si : Silicon(14)	P : Phosphorus(15)	S : Sulphur(16)
Ga : Gallium(31)	Ge : Germanium(32)	As : Arsenic(33)	Se : Selenium(34)
In : Indium(49)	Sn : Tin(50)	Sb: Antimony(51)	Te : Tellurium(52)
Tl : Thallium(81)	Pb : Lead(82)	Bi : Bismuth(83)	Po :Polonium(84)
Nh : Nihonium(113)	Fl: Flerovium(114)	Mc : Moscovium(115)	Lv : Livermorium(116)

Group 17	Group 18
	He : Helium (2)
F : Fluorine(9)	Ne : Neon(10)
Cl : Chlorine(17)	Ar : Argon(18)
Br : Bromine(35)	Kr : Krypton(36)
I : Iodine (53)	Xe : Xenon(54)
At : Astatine(85)	Rn : Radon(86)
Ts : Tennessine(117)	Og : Oganesson(118)

Lanthanoids(Group 3) / Lanthanides/Rare Earths

Ce : Cerium(58) Pr : Praseodymium(59) Nd: Neodymium(60) Tb :
Pm : Promethium(61) Sm: Samarium(62) Eu : Europium(63)
Gd : Gadolinium(64) Tb: Terbium(65) Dy : Dysprosium(66) Ho : Holmium(67)
Er : Erbium(68) Tm : Thulium(69) Yb : Ytterbium(70) Lu : Lutetium(71)

Actinoids(Group 3) / Actinides

Th : Thorium(90) Pa :Protactinium(91) U : Uranium (92) Np : Neptunium(93)
Pu : Plutonium(94) Am : Americium(95) Cm : Curium(96) Bk : Berkelium(97)
Cf : Californium(98) Es : Einsteinium(99) Fm: Fermium(100)
Md: Mendelevium(101) No : Nobelium(102) Lr : Lawrencium(103)

Gas, Liquid and Solid Elements

- Gas : 11 : H (H_2), N(N_2), O(O_2, O_3), F(F_2), Cl(Cl_2), He, Ne, Ar, Kr, Xe, Rn*
- Liquid: Br(Br_2) : Nonmetal and Hg : Metal (2)
  Ga, Cs, Fr, (Rb) (5/6)

* Solid : Rest

Latin names of elements whose common names are different

Na : Natrium(Sodium) Fe : Ferrum(Iron)
Hg : Hydragyrum(Mercury)
K : Kalium(Potassium)
Ag : Argentum(Silver) Pb : Plumbum(Lead)
Cu : Cuprum(Copper) Au : Aurum(Gold)
Sb: Stibium(Antimony)
Sn: Stannum(Tin)
W : Wolfram(Tungsten)
N.B: Wolfram is a Greek word

Modern Periodic Law

- The physical and chemical properties of elements are periodic functions of their atomic numbers(Z).
- Members of a family(Group) among Normal elements(s and p block) have identical valence shell configuration.
- d-block elements: similarities along group and also along each series.
- f-block elements: similarities along each series

Period-wise study of Elements

- 1^{st} Period: 2 elements (H, He)
- 2^{nd} Period: 8 elements (Li – Ne)
- 3^{rd} Period: 8 elements (Na – Ar)
- 4^{th} Period : 18 elements (8 normal + 10 Transition)
- 5^{th} Period: 18 elements (8 normal + 10 Transition)
- 6^{th} Period: 32 elements (8 normal + 9 Transition + 15 Lanthanides)
- 7^{th} Period: 32 elements (8 normal + 9 Transition + 15 Actinides)

Transition Series

- 3d Series (4^{th} Period) : Sc(21), Ti(22), V(23), Cr(24), Mn(25), Fe(26), Co(27), Ni(28), Cu(29), Zn(30) (1^{st} Transition Series)
  Anomalous EC : Cr, Cu
- 4d Series(5^{th} Period) : Y(39), Zr(40), Nb(41), Mo(42), Tc*(43), Ru(44), Rh(45), Pd(46), Ag(47), Cd(48) (2^{nd} T. Series)
  Anomalous EC: Nb, Mo, Ru, Rh, Pd, Ag
- 5d Series(6^{th} Period): La(57), Hf(72), Ta(73), W(74), Re(75), Os(76), Ir(77), Pt(78), Au(79), Hg(80) (3^{rd} T. series)
  Anomalous EC : Pt, Au
- 6d Series(7^{th} period) : Ac(89), Rf(104), Db(105), Sg(106), Bh(107), Hs(108), Mt(109), Ds(110),Rg(111), Cn(112)(4^{th} T.S)

Some Frequently Used Terms

- Bridge Elements: 2^{nd} Period
- Typical Elements: 3^{rd} Period
- *Diagonal Relationship*: Li – Mg, Be – Al, B – Si, C – P and so on
- Noble Metals: (Ru, Rh, Pd), (Os, Ir, Pt), Ag, Au (they are chemically inert and resistant to corrosion and do not react with oxygen, nitrogen and dilute acids)
- Platinum Group of Metals(PGM): (Ru, Rh, Pd), (Os, Ir, Pt)-They have similar properties and occur together in the same minerals. They are noble too.

19 Native Elements(Uncombined State)

Gold Group (Cu, Ag, Au)
Platinum Group(PGE): (Os, Ir, Pt)
Iron Group: Fe
Nitrogen Group: As, Sb, Bi,
Oxygen group: S, Se, Te
Zinc Group: Zn, Cd, Hg
Carbon Group:
C(diamond, graphite, fullerene), Sn, Pb

(Noble Gases, atmospheric gases are excluded in this list)

- Superheavy Metals: 104(Rf) – Og(118)
- Ferromagnetic Metals: Fe, Co, Ni, Gd
- Transactinide Elements: Same as Superheavy metals
- Transfermium Elements: Elements above Fermium(100).
- Transuranic Synthetic Elements which have been prepared in Bulk quantities: Np-237($t_{0.5}$=21.X10^6 yrs), Pu-239($t_{0.5}$=2.44X10^4 yrs), Am-241 ($t_{0.5}$=458 yrs), Cm-245($t_{0.5}$=17.6 yrs), Bk-247($t_{0.5}$=1380 yrs) , Cf-249($t_{0.5}$=351 yrs) (Upto Cf)

Other synthetic elements whose bulk material not produced:

- Og-294 : 5 atoms produced ($t_{0.5}$ = 0.9 ms)
- Ts-294: few mg produced ($t_{0.5}$=112 ms)
- Lv-293 : 3 atoms produced($t_{0.5}$=80 ms)
- Mc-288: 100 atoms produced($t_{0.5}$=0.65 s)
- Fl-290 : 1 atom produced at a time($t_{0.5}$=19s)
- Nh-286: 1 atom produced at a time($t_{0.5}$= 10 s)
- Cn-285: few atoms produced ($t_{0.5}$=30s)
- Rg-282 : few µg synthesized($t_{0.5}$=130 s)
- Ds-282: few mg synthesized($t_{0.5}$=130s)
- Mt-278: few mg synthesized($t_{0.5}$=4.5 s)

- Hs-277: few mg produced ($t_{0.5}$=130 s)
- Bh-270: few mg produced ($t_{0.5}$=2.3 min)
- Sg-267: few mg produced ($t_{0.5}$=9.8 min)
- Db-268: few mg produced ($t_{0.5}$=16 h)
- Rf-267: few mg produced ($t_{0.5}$=48 mins)
- Lr-266: few mg produced($t_{0.5}$=11 h)
- No-259: few mg produced($t_{0.5}$=58 min)
- Md-258: few g produced($t_{0.5}$=51.59 days)
- Fm-257: few g produced($t_{0.5}$=100.5 days)
- Es-255: few g produced($t_{0.5}$=39.8 days)

Tempoary IUPAC Naming

- Latin : nil(n)=0, un(u) =1, bi(b) =2, tri(t) =3, quad(q)=4, pent(p)=5, hex(h)=6, sept(s)=7, oct(o)=8, enn(e)=9. The suffix *ium* is added at the end.
- 119 : Hypothetical element in Group 1 : *Ununennium(Uue)*
- Hs(108) *:* was called as *Unniloctium*

10 Most Abundant Elements In Earth's Crust

Rank	Element	Abundance (percent by weight)
1	Oxygen	46.1%
2	Silicon	28.2%
3	Aluminum	8.23%
4	Iron	5.63%
5	Calcium	4.15%
6	Sodium	2.36%
7	Magnesium	2.33%
8	Potassium	2.09%
9	Titanium	0.565%
10	Hydrogen	0.140%

Isotopes/Nuclides

- Same element with different Mass numbers(A) and same atomic Number(Z).
- Polyisotopic elements, average atomic mass is determined from their relative natural abundance.
- $Av. Atomic\ Mass\ of\ Cl = \frac{3\times35+1\times37}{3+1} \approx 35.5$ (35:37 = 3:1)
- Av. Atomic Mass of Br = $\frac{1\times79+1\times81}{1+1} \approx 80$ (79:81 = 1:1)
- Av. Atomic Mass of O = $\frac{99.78\times16+0.02\times17+0.2\times18}{100} \approx 16$

Av. Atomic mass of Sn

$$= \frac{0.97\times112+0.66\times114+0.34\times115+14.5\times116+7.68\times117+2\quad .2\times118+8.59\times119+\quad .6\times120+4.63\times122+5.79\times124}{100}$$

=118.71

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses and relative abundance(%)	Average Atomic Mass(u/Da)
Ar	18	3	3	36(0.334%), 38(0.0630%), 40(99.6%), 37(trace, ε), 39(trace, β^-), 41 (trace, β^-)	39.948
Al	13	1	(1)	27(100%), 26*(trace, β^+, ε)	26.98
As	33	1	-	75(100%)	74.92
Ag	47	2	-	107(51.8%), 109(48.2%)	107.87
Au	79	1	-	197(100%)	196.97
Ac	89	-	2	225(trace, α), 227 (trace, β^-, α)	(227)
At	85	-	2	216(trace, α), 217 (traces,α)	[210]synth
Am	96	-	-		(243)synth
Ba	56	7	-	130(0.11%), 132(0.1%), 134(2.42%), 135(6.59%), 136(7.85), 137(11.2%), 138(71.7%)	137.34
Be	4	1	(2)	9(100%), 7(trace,ε) & 10 (trace, β^-)	9.012
Bi	83	1	1	209(100%, α), 210(trace, β^-, α)	208.98
B	5	2	-	10 (19%), 11(81%)	10.81
Br	35	2	-	79(50.6%), 81(49.4)	79.909

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses and relative abundance(%)	Average Atomic Mass(u/Da)
Bk	97	-	-		(247)
Ca	20	5	2	40(96.9%), 42(0.647%, 43(0.135%), 44(2.09%), 46(0.004%), 48(0.187%, β^-,β^-), 41(trace, ε)	40.08
Cd	48	8	-	106(1.25%), 108(0.89%), 110(12.5%), 111(12.8%), 112(24.1%), 113(12.2%), 114(28.8%), 116(7.51%)	112.4
C	6	2	1	12(98.9%), 13(1.1%), 14(trace, β^-)	12.011
Cs	55	1	(1)	133(100%), 135(trace, β^-)	132.905
Ce	58	4	-	136(0.186%), 138(0.251%), 140(88.4%), 142(11.1%)	140.12
Cl	17	2	(1)	35(76%), 37(24%), 36(trace, β^-, ε)	35.453
Cr	24	4	-	50(4.34%), 52(83.8%), 53(9.5%), 54(2.37%)	51.996
Co	27	1	(1)	59(100%), 60(trace, β^-)	58.93
Cu	29	2	-	63(69.2%), 65(30.8%)	63.54
Cm	96	-	-		(247)
Cf	98	-	-		(251)

Element	Atomic Number	No. of Stable Isotopes	No of Natural Radioactive Isotopes	Isotopic Masses with Relative Abundance(%)	Average Atomic Mass(u/Da)
Dy	66	7	-	156(0.056%), 158(0.095%), 160(2.33%), 161(18.9%), 162(25,5%), 163(24.9%), 164(28.3%)	162.50
Eu	63	1	1	153(52.2%), 151(47.8%, α)	151.96
Er	68	6	0	162(0.139%), 164(1.60%), 166(33.5%),167(22.9%), 168(27.0%), 170(14.9%)	167.26
Es	99	-	-		252
F	9	1	(1)	19(100%), 18(trace, β^+)	18.998
Fm	100	-	-		(257)
Fr	87	-	2		(221,223)
Fe	26	4	(1)	54(5.84%), 56(91.8%), 57(2.12%),58(0.28%), 60(trace, β^-)	55.845
Ga	31	2	-	69(60.1%), 71(39.9%)	69.72
Ge	32	5	-	70(20.5%), 72(27.4%), 73(7.76%), 74(36.5%), 76(7.75%, β^-, β^-)	72.63
Gd	64	6	1	154(2.18%), 155(14.8%), 156(20.5%), 157(15.7%), 158(24.8%), 160(21.9%), 152(0.2%, α)	157.25

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses with Relative Abundance(%)	Average Atomic Mass(u/Da)
He	2	2	-	3(0.0002%), 4(99.9998%)	4.003
Ho	67	1	-	165(100%)	164.93
H	1	2	1	1(99.9855), 2(0.0145%), 3(trace, β^-)	1.00797
Hg	80	7	-	196(0.15%), 198(10.0%), 199(16.9%), 200(23.1%), 201(13.2%), 202(29.7%), 204(6.82%)	200.59
Hf	72	5	1	176(5.26%), 177(18.6%), 178(27.3%), 179(13.6%), 180(35.1%), 174(0.16%,α)	178.49
In	49	1	1	113(4.28%), 115(95.7%, β^-)	114.82
I	53	1	(1)	127(100%), 129(trace, β^-)	126.90
Ir	77	2	-	191(37.3%). 193(62.7%)	192.22
K	19	2	1	39(93.3%), 41(6.73%), 40(0.012%,β^-,ε)	39.102
Kr	36	5	3	80(2.29%), 82(11.6%), 83(11.5%), 84(57%), 86(17.3%), 78(0.36%,ε,ε), 81(trace,e) 85(trace,β^-)	83.798
Li	3	2	-	6(1.9%), 7(98.1%)	6.939

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses with Relative Abundance(%)	Average Atomic Mass(u/Da)
La	57	1	1	139(99.911%), 138(0.089%, ε, β^-)	138.91
Lu	71	1	1	175(97.4%), 176(2.6%, β^-, ε)	174.967
Mg	12	3	-	24(79%), 25(10.0%), 26(11.0%)	24.305
Mn	25	1	(1)	55(100%), 53(trace, ε)	54.938
Mo	42	6	1	92(14.7%), 94(9.19%), 95(15.9%), 96(16.7%), 97(9.58%), 98(24.3%), 100(9.74%, β^-,β^-)	95.95
Md	101	-	-		(258)
Na	11	1	(2)	23(100%), 22(trace, β^+), 24(trace, β^-)	22.989
Ne	10	3	-	20(90.5%), 21(0.27%), 22(9.25%)	20.183
Ni	28	5	(1)	58(68.1%), 60(26.2%), 61(1.14%), 62(3.63%), 64(0.926%), 59(trace, ε)	58.693
Nb	41	1	(2)	93(100%), 92(trace, β^+), 94(trace, β^-)	92.91
N	7	2	(1)	14(99.6%), 15(0.4%), 13(trace, β^+)	14.007

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses with Relative Abundance(%)	Average Atomic Mass(u/Da)
Nd	60	5	2	142(27.2%), 143(12.2%), 145(8.3%), 146(17.2%), 148(5.8%), 144(23.8%, α), 150(5.6%, β^-, β^-)	144.24
Np	93	-	2	237(trace, α), 239(trace, β^-)	(237)
Os	76	5	2	187(1.96%), 188(13.2%), 189(16.1%), 190(26.3%), 192(40.8%), 184(0.02%, α), 186(1.59%, α)	190.23
O	8	3	-	16(99.8%), 17(0.038%), 18(0.205%)	15.999
Pd	46	6	(1)	102(1.02%), 104(11.1%), 105(22.3%), 106(27.3%), 108(26.5%), 110(11.7%), 107(trace, β^-)	106.42
P	15	1	(2)	31(100%), 32(trace, β^-), 33(trace, β^-)	30.974
Pr	59	1	-	141(100%)	140.91
Po	84	-	1	210(trace, α)	(209)synth
Pt	78	5	(1)	192(0.782%), 194(32.9%), 195(33.8%), 196(25.2%), 198(7.36%), 190(0.012%, α)	195.09
Pm	61	-	1	147(trace, β^-)	(147)

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses with Relative Abundance(%)	Average Atomic Mass(u/Da)
Pb	82	4	(6)	204(1.4%), 206(24.1%), 207(22.1%), 208(52.4%), 205(trace,ε), 209(trace, β^-), 210(trace, β^-,α), 211(trace,β^-), 212(trace, β^-), 214(trace, β^-)	207.19
Pa	91	-	3	231(100%, α), 233(trace, β^-), 234(trace,β^-)	231.04
Pu	94	-	4	238(trace, α), 239(trace, α, SF), 240(trace, α.SF),244(trace,α,SF)	(244)
Re	75	1	1	185(37.4%), 187(62.6%, β^-)	186.21
Rh	45	1	-	103(100%)	102.905
Rb	37	1	1	85(72.2%), 87(27.8%, β^-)	85.467
Ru	44	7	-	96(5.54%), 98(1.87%), 99(12.8%), 100(12.6%), 101(17.1%), 102(31.6%), 104(18.6%)	101.07
Rn	86	-	1	222(trace, α)	(222)
Sc	21	1	-	45(100%)	44.96
Se	34	5	2	74(0.86%), 76(9.23%), 77(7.60%), 78(23.7%), 80(49.8%), 79(trace, β^-), 82(8.82%, β^-, β^-)	78.96

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses with Relative Abundance(%)	Average Atomic Mass(u/Da)
Si	14	3	(2)	28(92.2%), 29(4.7%), 30(3.1%), 31(trace, β^-), 32(trace, β^-)	28.09
Sb	51	2	-	121(57.2%), 123(42.8%)	121.75
Sr	38	4	st		87.62
S	16	4	(1)	32(94.8%), 33(0.76%), 34(4.37%), 36(0.02%), 35(trace, β^-)	32.064
Sn	50	10	1	88(82.6%), 87(7%), 86(9.86%), 84(0.56%), 90(trace, β^-)	118.95
Sm	62	5	3	144(3.08%), 149(13.8%), 150(7.37%), 152(26.7%), 154(22.7%), 147(15%, α), 148(11.3%, α), 146(trace, α)	150.36
Ta	73	2	-	181(99.998%), 180(0.012%)	180.95
Te	52	8	-	120(0.09%), 122(2.55%), 123(0.89%), 124(4.74%), 125(7.07%), 126(18.8%), 128(31.7%, β,β), 130(34.1%, β,β)	127.60
Tb	65	1	-	159(100%)	158.92
Tl	81	2	-	203(29.5%), 205(70.5%)	204.37
Ti	22	5	-	46(8.25%, 47(7.44%), 48(73.7%), 49(5.41%), 50(5.18%)	47.867
Tm	69	1	-	169(100%)	168.93

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Isotopic Masses with Relative Abundance(%)	Average Atomic Mass(u/Da)
Tc	43	-	(1)	99(trace, β)	(99)
Th	89	-	8	232(100%), 227(trace,α), 228(trace, α), 229(trace, α), 230(0.02%, α), 231(trace, β), 233(trace, β), 234(trace, β)	232.04
U	92	-	5	238(99.3%,α,SF), 233(trace, α,SF), 234(0.005%, α,SF), 235(0.72%, α,SF), 236(trace, α,SF),	238.03
V	23	1	1	51(99.75%), 50(0.25%, β^+)	50.94
W	74	5	-	180(0.12%,α), 182(26.5%, 183(14.3%), 184(30.6%), 186(28.4%)	183.85
Xe	54	9	-	124(0.095%, ε,ε), 126(0.089%), 128(1.91%), 129(26.4%), 130(4.07%), 131(21.2%), 132(26.9%), 134(10.4%), 136(8.86%,-β^-,β^-)	131.29
Y	39	1	-	89(100%)	88.905
Yb	70	7	-	168(0.126%), 170(3.02%), 171(14.2%), 172(21.8%), 173(16.1%), 174(31.9%), 176(12.9%)	173.05
Zn	30	5	-	64(49.2%), 66(27.7%), 67(4.0%), 68(18.5%), 70(0.6%)	65.37
Zr	40	5	-	90(51.1%), 91(11.2%), 92(17.1%), 94(17.4%), 96(2.8%, β^-, β^-)	91.22

Element	Atomic Number	No of Stable Isotopes	Number of Natural Radioactive Isotopes	Average Atomic Mass(u/Da)
No	102	-	-	(259)
Lr	103	-	-	(266)
Rf	104	-	-	(267)
Db	105	-	-	(268)
Sg	106	-	-	(269)
Bh	107	-	-	(270)
Hs	108	-	-	(277)
Mt	109	-	-	(278)
Ds	110	-	-	(281)
Rg	111	-	-	(282)
Cn	112	-	-	(285)
Nh	113	-	-	(286)
Fl	114	-	-	(289)
Mc	115	-	-	(290)
Lv	116	-	-	(293)
Ts	117	-	-	(294)
Og	118	-	-	(294)

19 Monoisotopic Elements

$^{9}_{4}Be$ $^{19}_{9}F$ $^{23}_{11}Na$ $^{27}_{13}Al$ $^{31}_{15}P$ $^{55}_{25}Mn$ $^{59}_{27}Co$

$^{85}_{37}Rb$ $^{127}_{53}I$ $^{133}_{55}Cs$ $^{197}_{79}Au$

$^{45}_{21}Sc$ $^{75}_{33}As$ $^{89}_{39}Y$ $^{93}_{41}Nb$ $^{103}_{45}Rh$ $^{141}_{59}Pr$

$^{159}_{65}Tb$ $^{165}_{67}Ho$ $^{169}_{69}Tm$

Thought Provoking Questions

- SAQ 1: Why K-40 is unstable and is radioactive while K-41 is more abundant than K-40 and is stable.
- Ans: K-40 has 21 neutrons(odd) and hence has neutron asymmetry with one unpaired neutron. This gives it greater deformation from spherical symmetry and gives greater electrical quadrupole moment for which it becomes unstable with lower binding energy. So odd-neutron number is the key to instability. It decays by beta emission(89%) and electron capture(11%)
- K-41 has 22 neutrons and all are paired. This gives greater symmetry of the nucleus, lower quadrupole moment and greater binding energy and hence stable. The greater n/p ratio in K-41 is compensated by the symmetry due to even number of protons. So in this case even-neutron is the key.

- SAQ: Why Ca-48 is radioactive even if has magic number of protons(20) and magic number of neutrons(28) ?
- Ans: Even though Ca-48 is radioactive which undergoes double beta decay process with a high half life period of 6.4 X 10^{19} years(a billion times greater the age of universe). Virtually it is a stable isotope. But due to high n/p ratio, it is radioactive.
- SAQ: Is Bi-209 is radioactive ? Explain ?
- Ans: In 2003, it was discovered that Bi-209 undergoes alpha decay with half life period of 1.9 X 10^{19} years. So virtually it is a stable nuclide, but it is considered now to be radioactive.
- **SAQ**: Which elements expand on freezing like water ?
- Ans: Bi, Sb, Ga, Ge, Si