

PTU-SYLLABUS

Unit V Periodic properties

Effective nuclear charge, penetration of orbitals, variations of s, p, d and f orbital energies of atoms in the periodic table, electronic configurations, atomic and ionic sizes, ionization energies, electron affinity and electronegativity, polarizability, oxidation states, hard soft acids and bases, molecular geometries.

Relating chemical and physical properties to the table

- **Mendeleev's table was constructed 50 years before the discovery of the nucleus**
- **The arrangement of elements was by atomic weight**
- **Atomic number(Moseley 1911) provides a more systematic ordering according to atomic number .**

PERIOD NUMBER		Representative elements		<i>d</i> -Transition elements										Representative elements					Noble gases
		GROUP NUMBER												GROUP NUMBER					GROUP NUMBER
		1	2											13	14	15	16	17	18
		IA	IIA											III B	IV B	V B	VI B	VII B	0
1				1 H 1s ¹															2 He 1s ²
2		3 Li 2s ¹	4 Be 2s ²											5 B 2s ² 2p ¹	6 C 2s ² 2p ²	7 N 2s ² 2p ³	8 O 2s ² 2p ⁴	9 F 2s ² 2p ⁵	10 Ne 2s ² 2p ⁶
3		11 Na 3s ¹	12 Mg 3s ²	3 III A	4 IVA	5 VA	6 VIA	7 VIIA	8 ← VIII →	9	10	11 IB	12 II B	13 Al 3s ² 3p ¹	14 Si 3s ² 3p ²	15 P 3s ² 3p ³	16 S 3s ² 3p ⁴	17 Cl 3s ² 3p ⁵	18 Ar 3s ² 3p ⁶
4		19 K 4s ¹	20 Ca 4s ²	21 Sc 3d ¹ 4s ²	22 Ti 3d ² 4s ²	23 V 3d ³ 4s ²	24 Cr 3d ⁵ 4s ¹	25 Mn 3d ⁵ 4s ²	26 Fe 3d ⁶ 4s ²	27 Co 3d ⁷ 4s ²	28 Ni 3d ⁸ 4s ²	29 Cu 3d ¹⁰ 4s ¹	30 Zn 3d ¹⁰ 4s ²	31 Ga 4s ² 4p ¹	32 Ge 4s ² 4p ²	33 As 4s ² 4p ³	34 Se 4s ² 4p ⁴	35 Br 4s ² 4p ⁵	36 Kr 4s ² 4p ⁶
5		37 Rb 5s ¹	38 Sr 5s ²	39 Y 4d ¹ 5s ²	40 Zr 4d ² 5s ²	41 Nb 4d ⁴ 5s ¹	42 Mo 4d ⁵ 5s ¹	43 Tc 4d ⁵ 5s ²	44 Ru 4d ⁷ 5s ¹	45 Rh 4d ⁸ 5s ¹	46 Pd 4d ¹⁰	47 Ag 4d ¹⁰ 5s ¹	48 Cd 4d ¹⁰ 5s ²	49 In 5s ² 5p ¹	50 Sn 5s ² 5p ²	51 Sb 5s ² 5p ³	52 Te 5s ² 5p ⁴	53 I 5s ² 5p ⁵	54 Xe 5s ² 5p ⁶
6		55 Cs 6s ¹	56 Ba 6s ²	57 La* 5d ¹ 6s ²	72 Hf 4f ¹⁴ 5d ² 6s ²	73 Ta 5d ³ 6s ²	74 W 5d ⁴ 6s ²	75 Re 5d ⁵ 6s ²	76 Os 5d ⁶ 6s ²	77 Ir 5d ⁷ 6s ²	78 Pt 5d ⁹ 6s ¹	79 Au 5d ¹⁰ 6s ¹	80 Hg 5d ¹⁰ 6s ²	81 Tl 6s ² 6p ¹	82 Pb 6s ² 6p ²	83 Bi 6s ² 6p ³	84 Po 6s ² 6p ⁴	85 At 6s ² 6p ⁵	86 Rn 6s ² 6p ⁶
7		87 Fr 7s ¹	88 Ra 7s ²	89 Ac** 6d ¹ 7s ²	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo

f- Inner transition elements

f - Inner transition elements

* Lanthanoids
 $4f^n 5d^0 6s^2$

** Actinoids
 $5f^n 6d^0 7s^2$

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
$4f^1 5d^0 6s^2$	$4f^2 5d^0 6s^2$	$4f^3 5d^0 6s^2$	$4f^4 5d^0 6s^2$	$4f^5 5d^0 6s^2$	$4f^6 5d^0 6s^2$	$4f^7 5d^0 6s^2$	$4f^7 5d^1 6s^2$	$4f^9 5d^0 6s^2$	$4f^{10} 5d^1 6s^2$	$4f^{11} 5d^0 6s^2$	$4f^{12} 5d^0 6s^2$	$4f^{13} 5d^0 6s^2$	$4f^{14} 5d^0 6s^2$
90	91	92	93	94	95	96	97	98	99	100	101	102	103
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
$5f^0 6d^2 7s^2$	$5f^2 6d^1 7s^2$	$5f^3 6d^1 7s^2$	$5f^4 6d^1 7s^2$	$5f^6 6d^0 7s^2$	$5f^7 6d^0 7s^2$	$5f^7 6d^1 7s^2$	$5f^9 6d^0 7s^2$	$5f^{10} 6d^0 7s^2$	$5f^{11} 6d^0 7s^2$	$5f^{12} 6d^0 7s^2$	$5f^{13} 6d^0 7s^2$	$5f^{14} 6d^0 7s^2$	$5f^{14} 6d^0 7s^2$

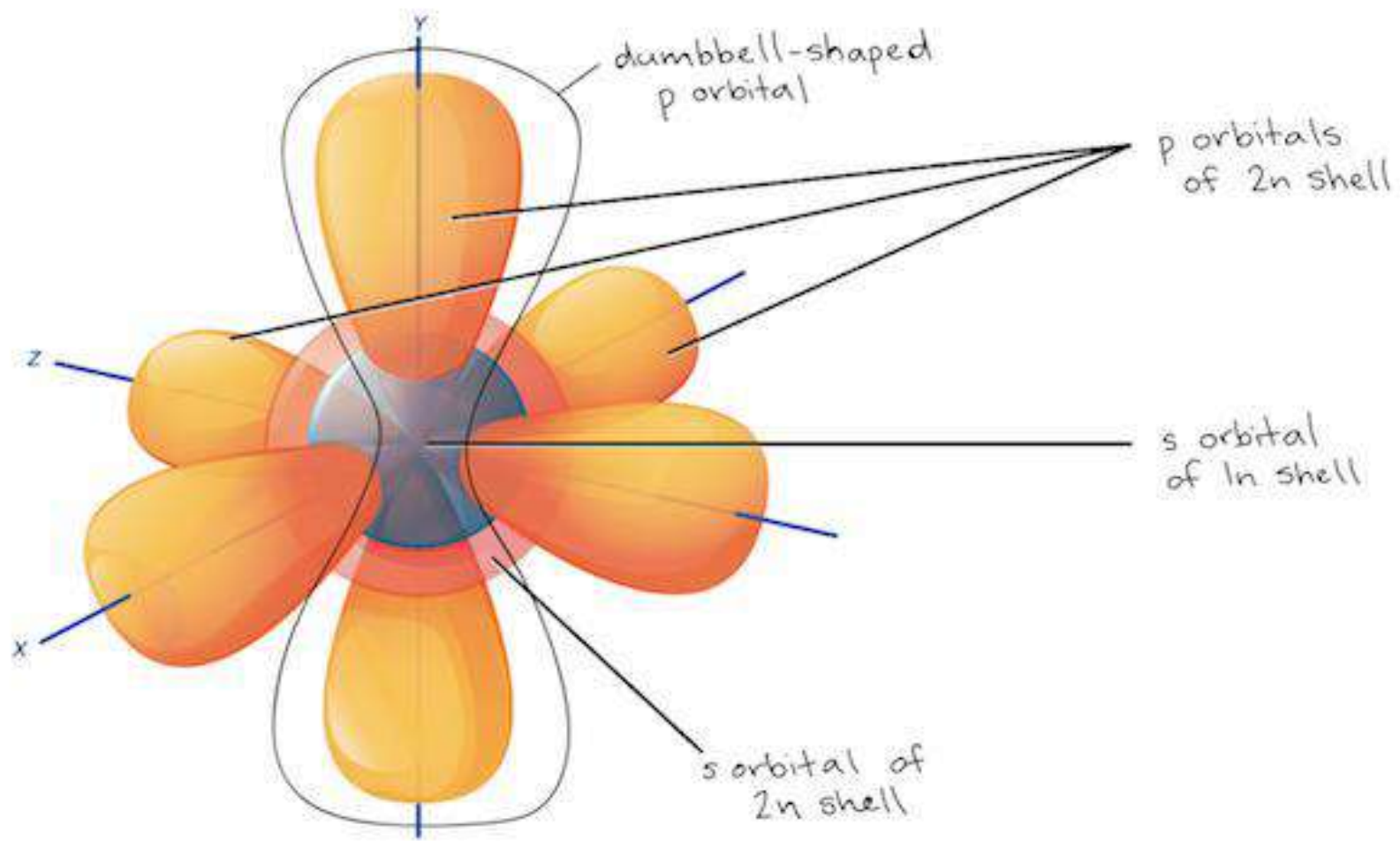
Fig. 3.2 Long form of the Periodic Table of the Elements with their atomic numbers and ground state outer electronic configurations. The groups are numbered 1-18 in accordance with the 1984 IUPAC recommendations. This notation replaces the old numbering scheme of IA-VIIA, VIII, IB-VIIB and 0 for the elements.

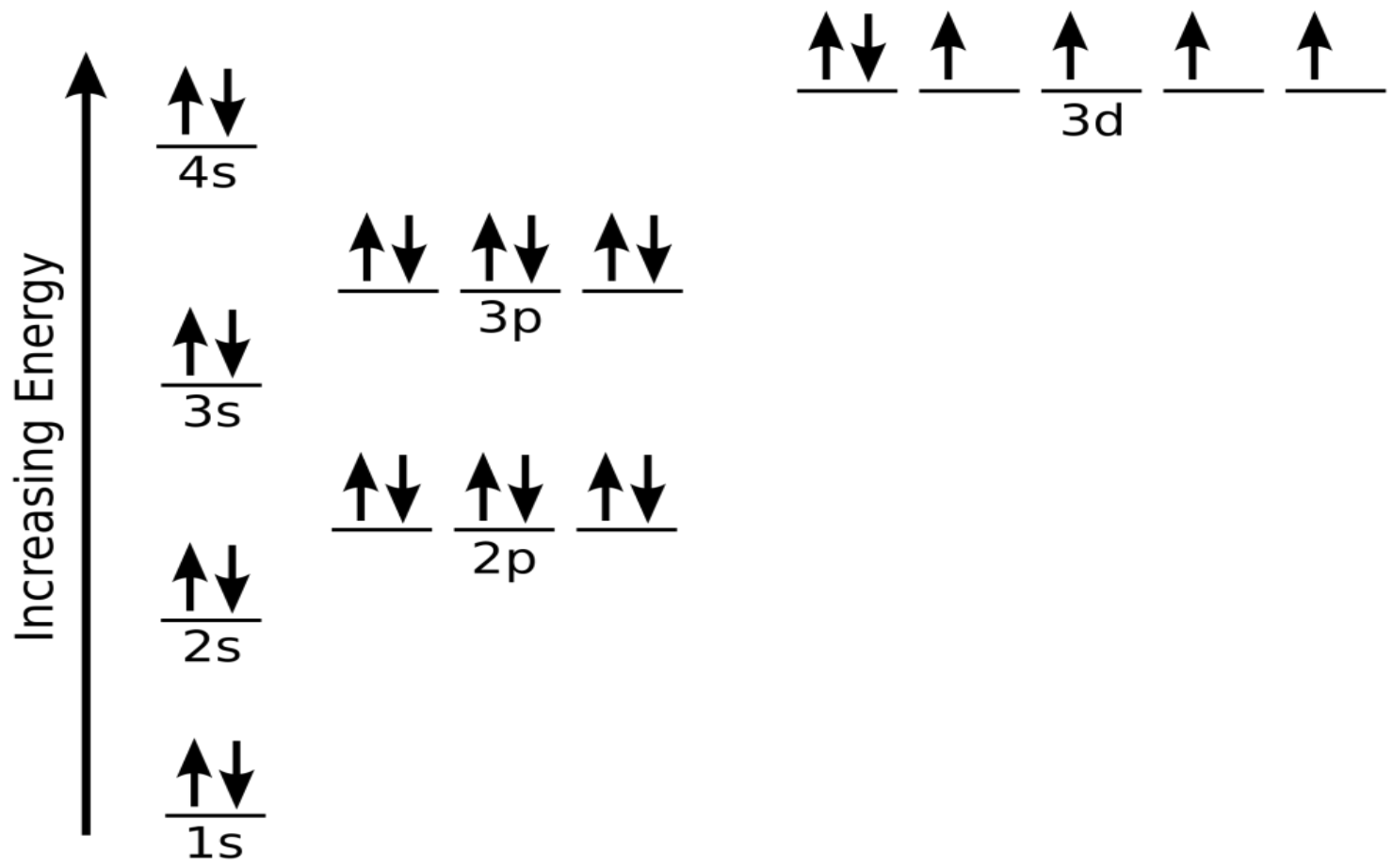
Notation for IUPAC Nomenclature of Elements

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

Nomenclature of Elements with atomic Number above 100

Atomic Number	Name according to IUPAC nomenclature	Symbol	IUPAC Official Name	IUPAC Symbol
101	Unnilunium	Unu	Mendelevium	Md
102	Unnilbium	Unb	Nobelium	No
103	Unniltrium	Unt	Lawrencium	Lr
104	Unnilquadium	Unq	Rutherfordium	Rf
105	Unnilpentium	Unp	Dubnium	Db
106	Unnilhexium	Unh	Seaborgium	Sg
107	Unnilseptium	Uns	Bohrium	Bh
108	Unniloctium	Uno	Hassium	Hs
109	Unnilennium	Une	Meitnerium	Mt
110	Ununillium	Uun	Darmstadtium	Ds
111	Unununium	Uuu	Rontgenium	Rg
112	Ununbium	Uub	Copernicium	Cn
113	Ununtrium	Uut	*	-
114	Ununquadium	Uuq	Flerovium	Fl
115	Ununpentium	Uup	*	-
116	Ununhexium	Uuh	Livermorium	Lv
117	Ununseptium	Uus	*	-
118	Ununoctium	Uuo	*	-

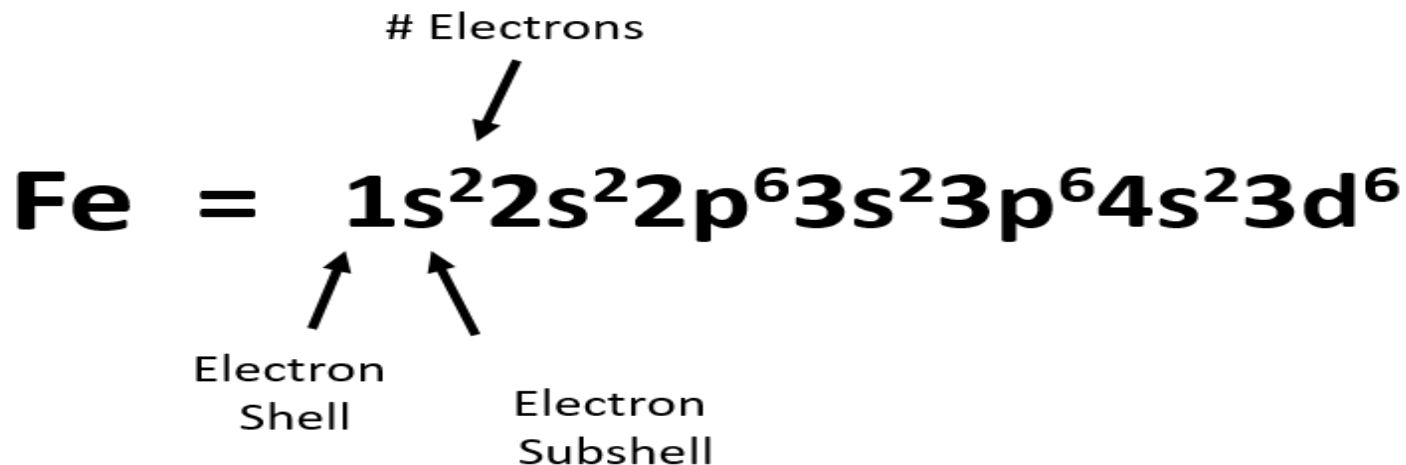




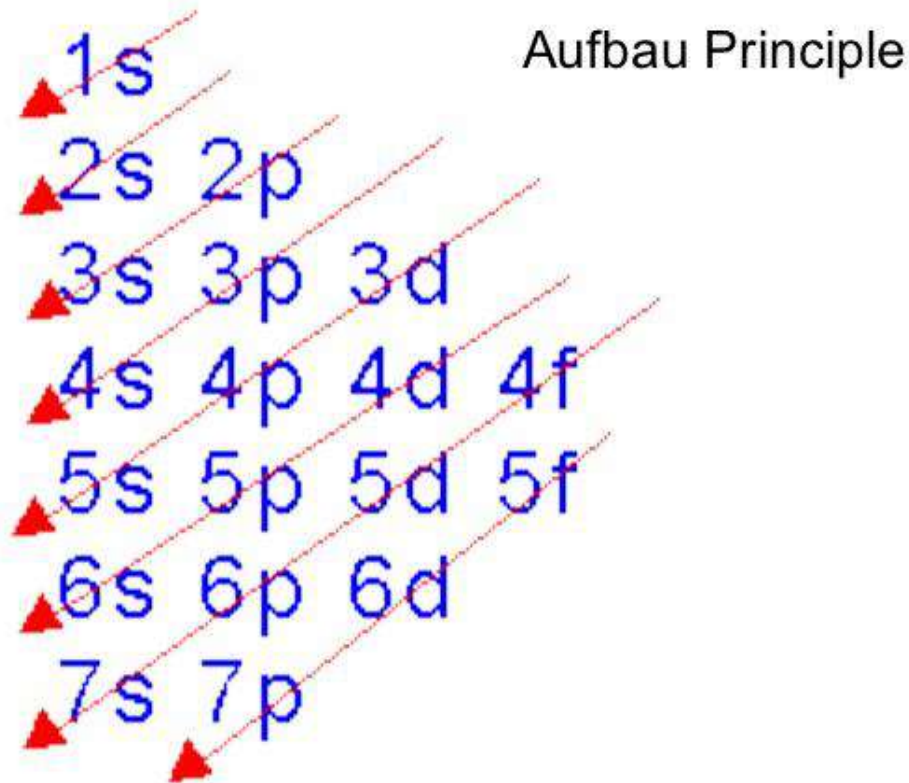
Electronic Configuration Of Atoms

The distribution of electrons into different levels, subshells and orbital's of an atom is called as electronic configuration

The filling of electrons is governed by Aufbau's principle, Pauli Exclusion principle and Hunds rule of maximum multiplicity.



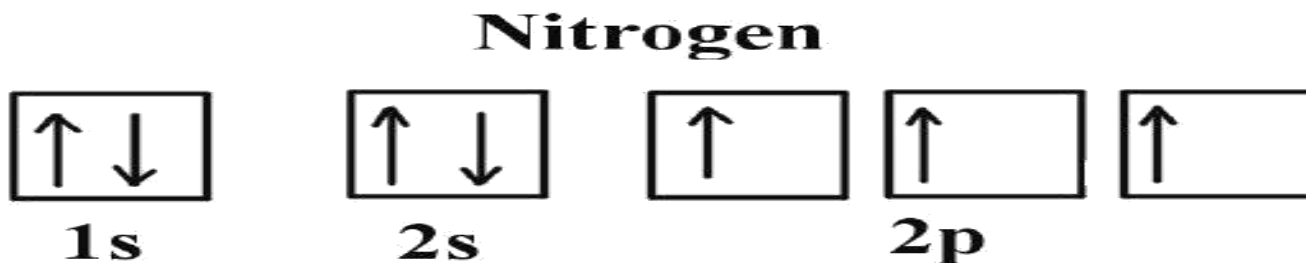
Filling order Diagram



Electronic Configuration Of Atoms

Pauli Exclusion principle

The *Pauli Exclusion Principle* states that, in an atom or molecule, no two electrons can have the same four electronic quantum numbers. As an orbital can contain a maximum of only two electrons, the two electrons must have opposing spins.



Electronic Configuration Of Atoms

Example of Hund's Rule:

p orbital with 6 electrons

Step 1

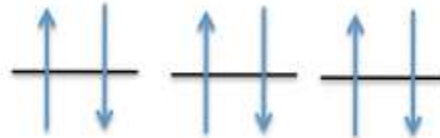
p orbital



Fill all orientations with $+\frac{1}{2}$ spin electrons first

Step 2

p orbital



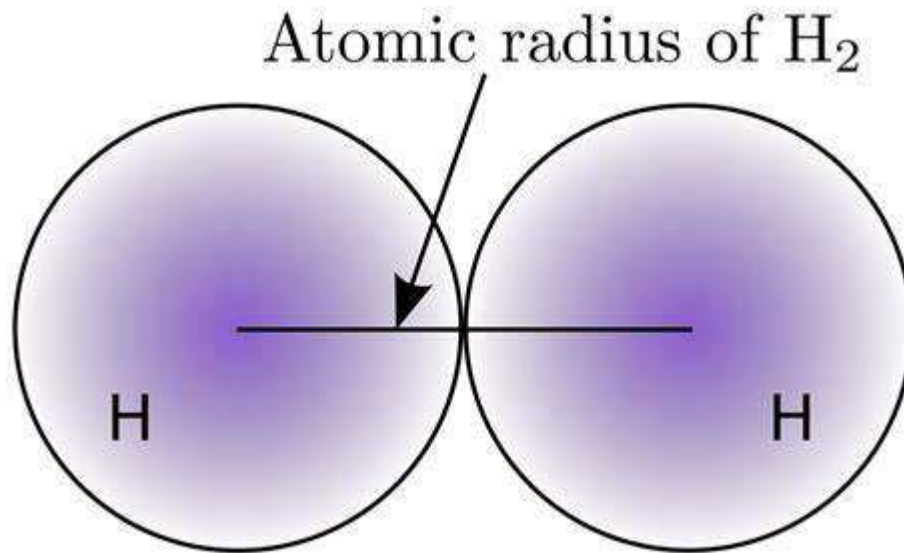
Then complete orientations with $-\frac{1}{2}$ spin electrons

ATOMIC RADIUS

Definition: Atomic radius is the measure of the size of an atom, usually represented as the distance between the nucleus of an atom and its outermost electron.

Importance: Understanding atomic radius provides insights into the physical and chemical properties of elements.

ATOMIC RADIUS



Trends in Atomic Radius

Periodic Trend: Atomic radius generally increases down a group (from top to bottom) in the periodic table.

Periodic Trend: Atomic radius generally decreases across a period (from left to right) in the periodic table.

Factors Influencing Atomic Radius

Nuclear Charge: Increased nuclear charge attracts electrons more strongly, reducing atomic radius.

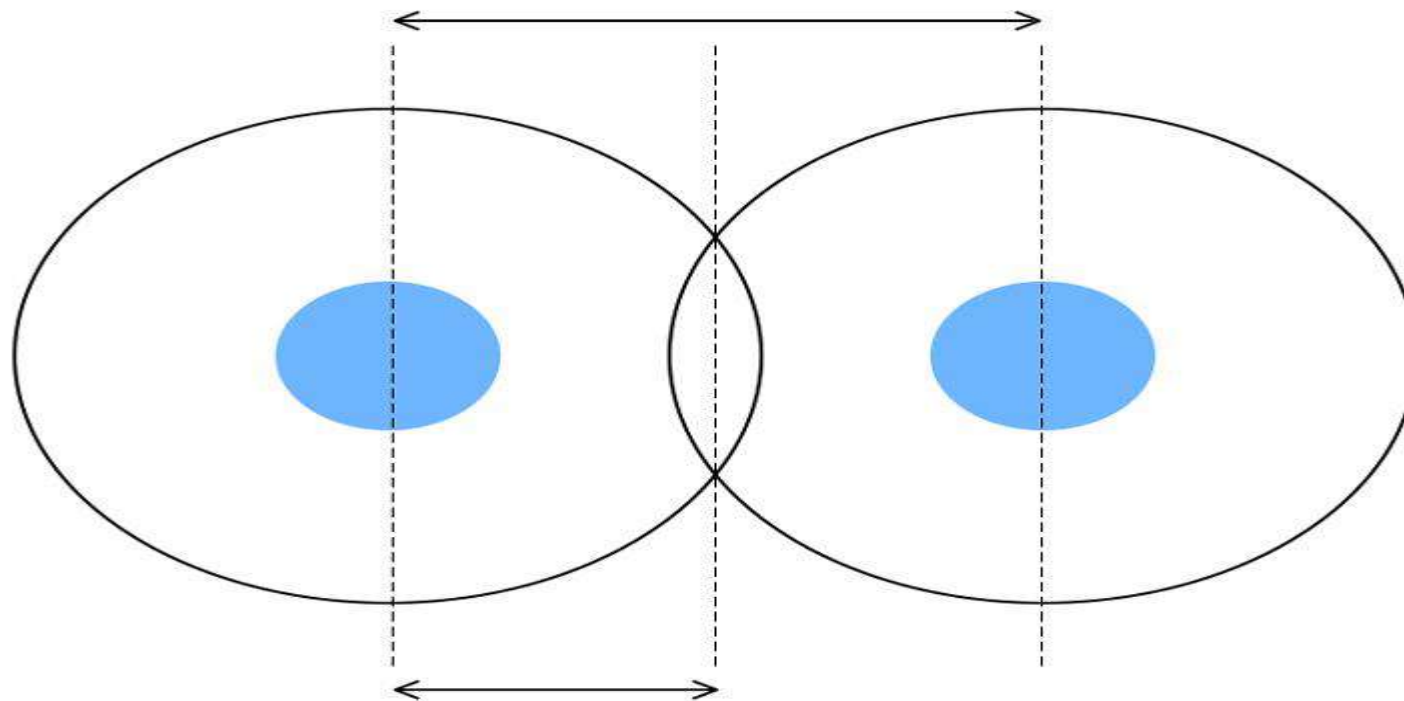
Electron-Electron Repulsion: Increased electron-electron repulsion in outer shells can lead to a larger atomic radius.

TYPES OF ATOMIC RADIUS

- VANDER WAAL RADIUS
- COVALENT RADIUS
- IONIC RADIUS
- METALLIC RADIUS

Covalent Radius

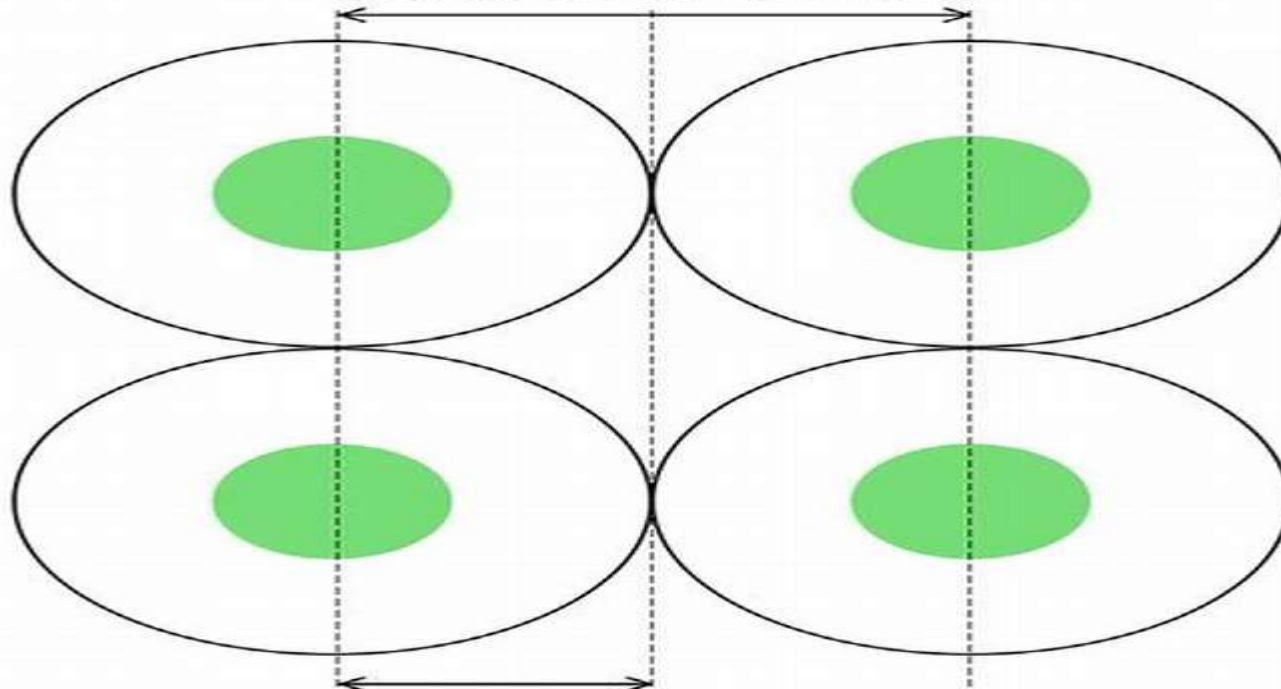
Distance between two nuclei



Covalent radius = Half the distance
between the two nuclei

Metallic Radius

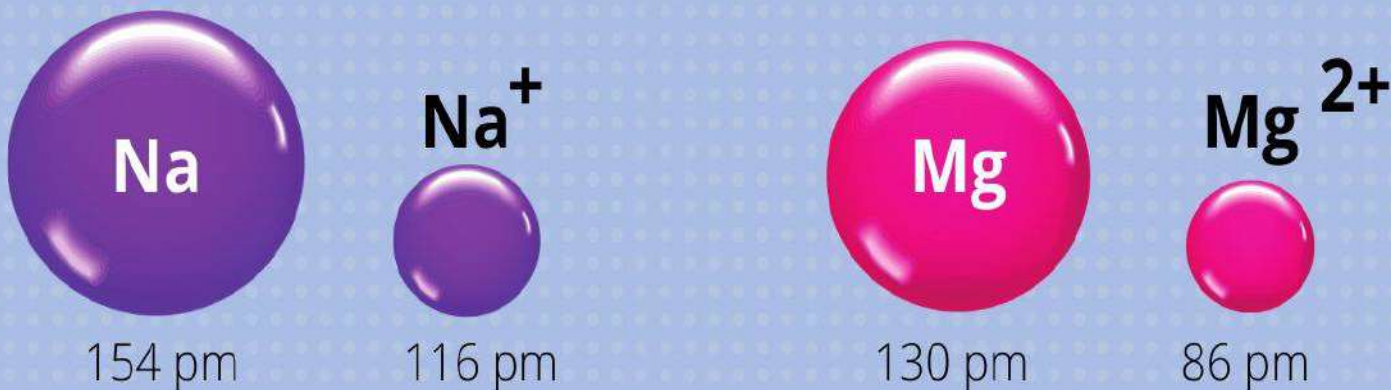
Distance between two nuclei



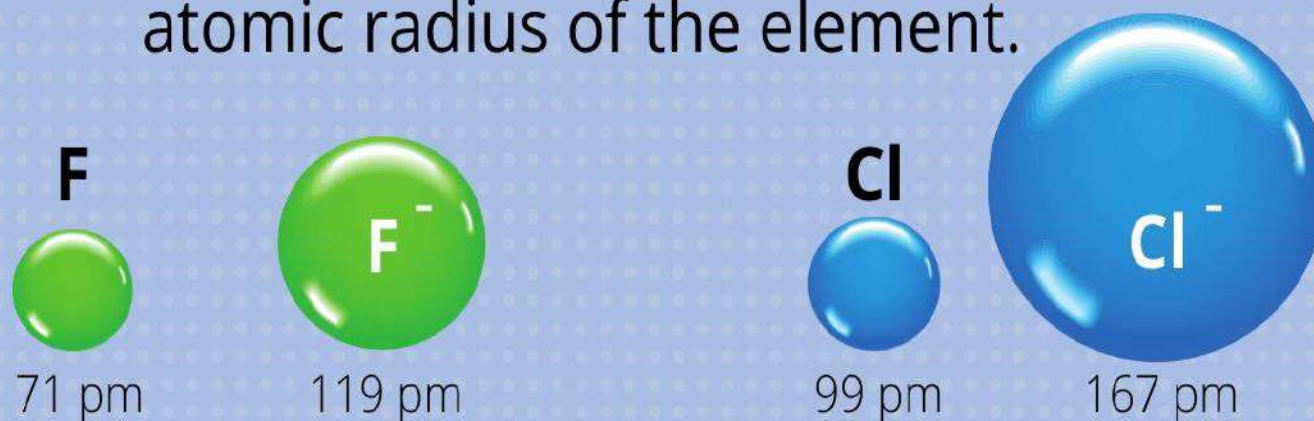
Metallic radius = Half the distance between the two nuclei

Atomic Radius vs Ionic Radius

The ionic radius of a positive ion is smaller than atomic radius of the element.



The ionic radius of a negative ion is larger than atomic radius of the element.





152 pm



60 pm



111 pm



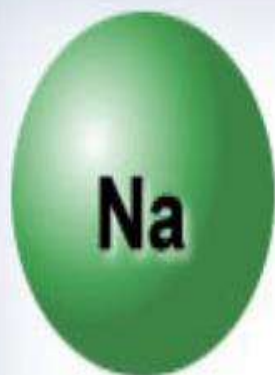
31 pm



64 pm



136 pm



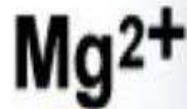
186 pm



95 pm



160 pm



65 pm

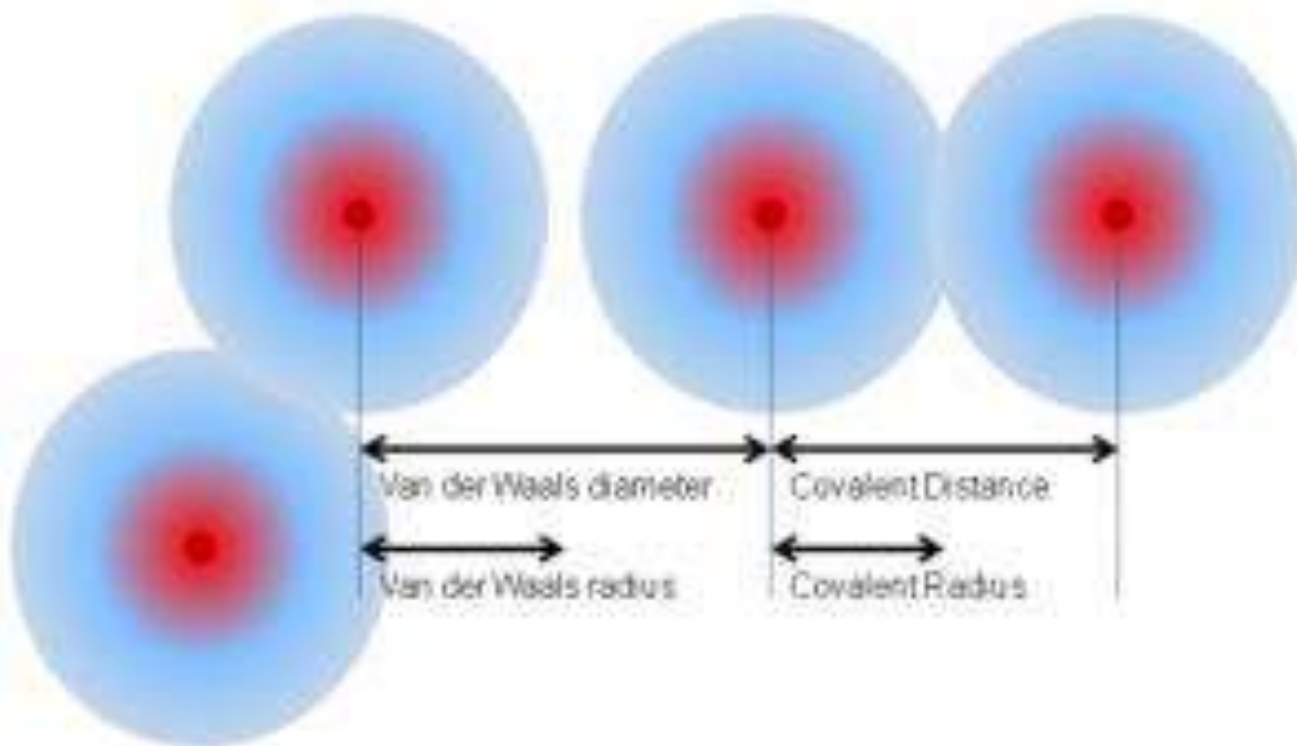


99 pm

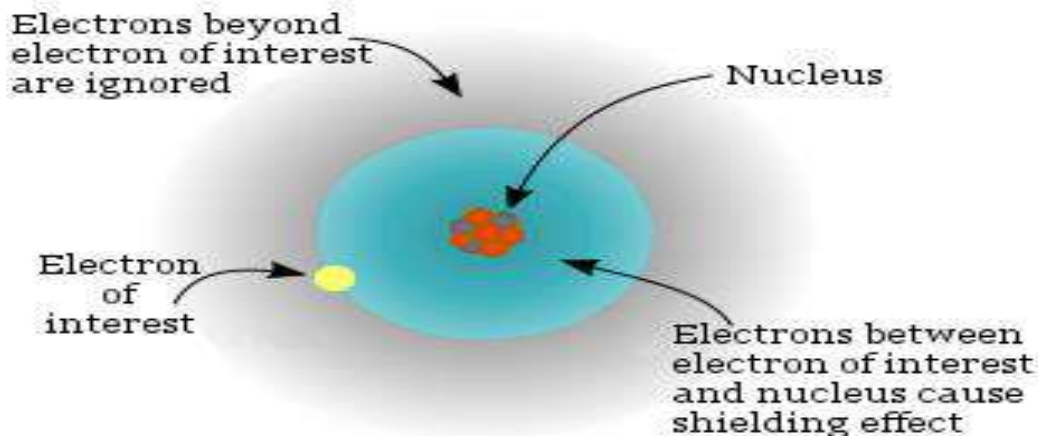


181 pm

VAN DER WAAL RADIUS



Penetration of Orbital's



- Penetration Power means the ability of an orbital to attract an electron. This process is accompanied with release of energy.

Penetration of Orbital's

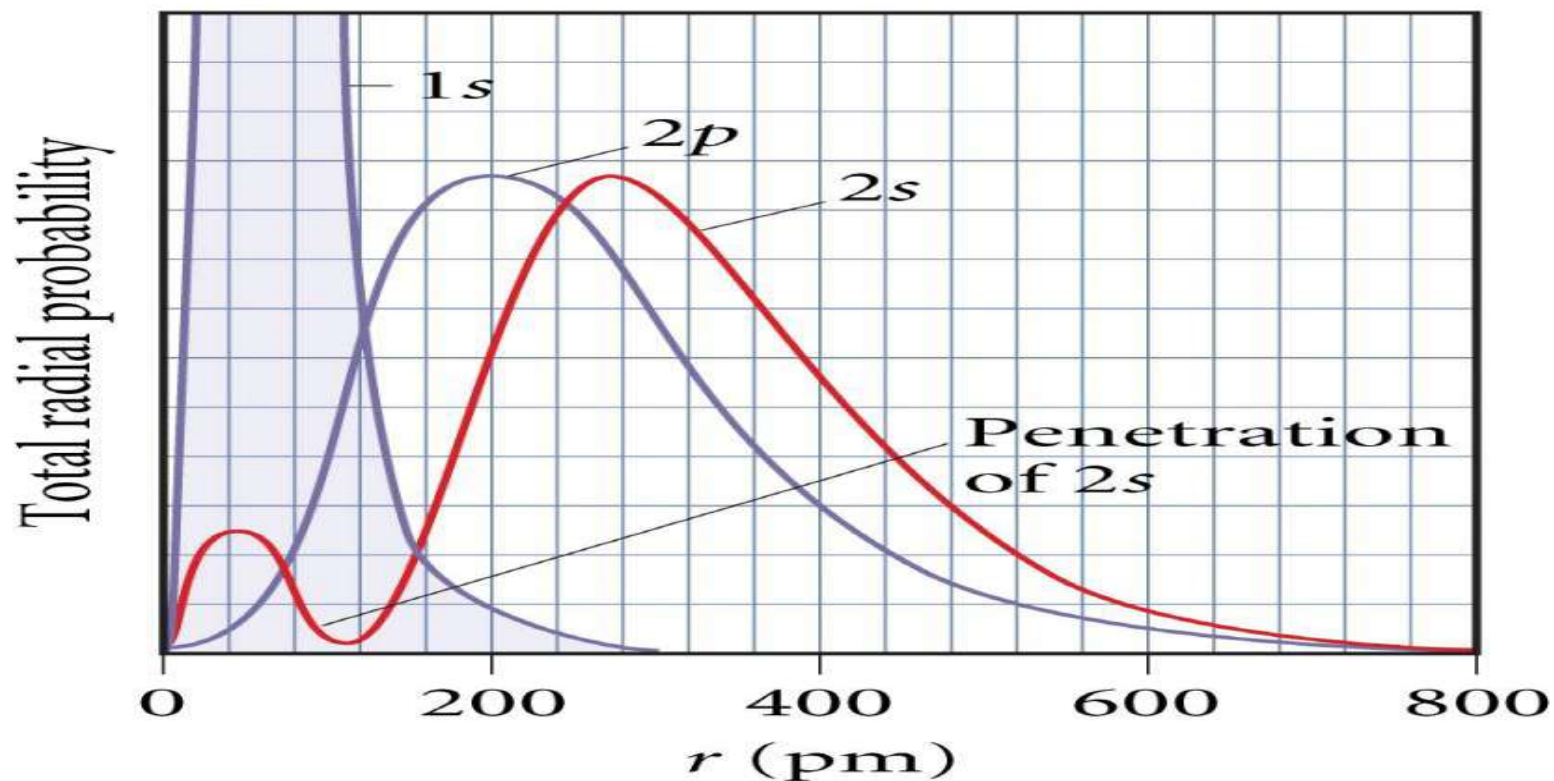
The Penetration effect of s orbital is the maximum because of the closeness to the nucleus than are the p, d and f orbital's.

Thus an s orbital, due it's more penetration effect, releases greater amount of energy than p orbital when it accepts an electron.

Similarly the energy released by a d orbital is more than that of a f orbital but less than that of a p orbital .

Inner shell (core) electrons screen the outer (valence) electrons from the nuclear charge

Penetration of Orbital's



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Effective Nuclear Charge

The effective nuclear charge is the net positive charge experienced by valence electrons.

It can be approximated by the equation:

$$Z_{\text{eff}} = Z - S,$$

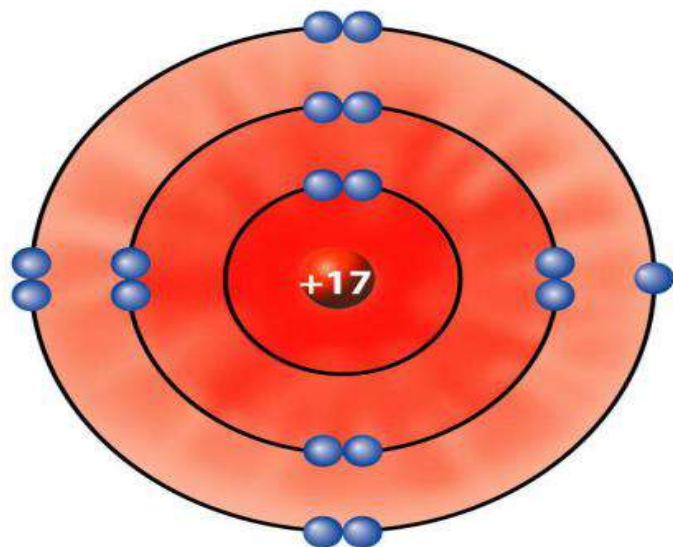
where Z is the atomic number and

S is the number of shielding electrons.

Shielding and effective nuclear charge

- The “shell” picture helps to explain these observations
- Electrons in same shell experience stronger attraction to nucleus as shell fills

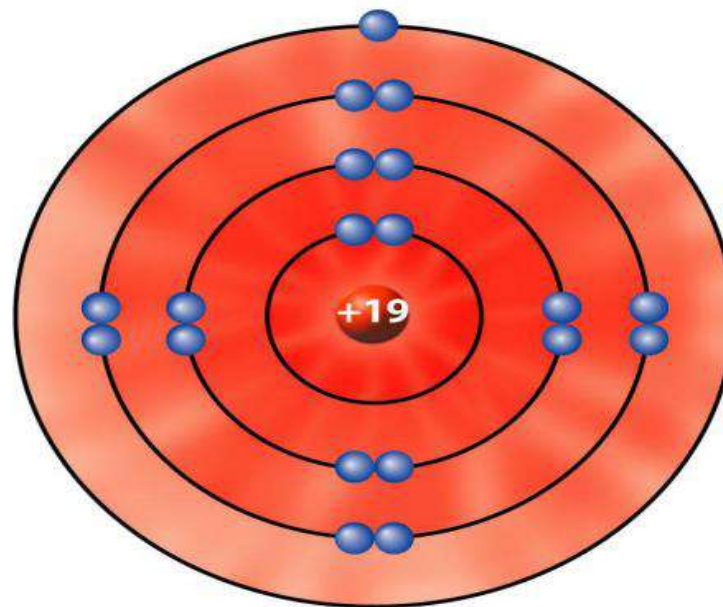
Effective Nuclear Charge



Chlorine

$$\begin{array}{r} +17 \text{ Actual nuclear charge} \\ -10 \text{ Inner shell electrons} \\ \hline +7 \text{ Effective nuclear charge} \end{array}$$

(a)



Potassium

$$\begin{array}{r} +19 \text{ Actual nuclear charge} \\ -18 \text{ Inner shell electrons} \\ \hline +1 \text{ Effective nuclear charge} \end{array}$$

(b)

Ionization energy (I)

The energy required to remove an electron from an isolated gaseous atom.



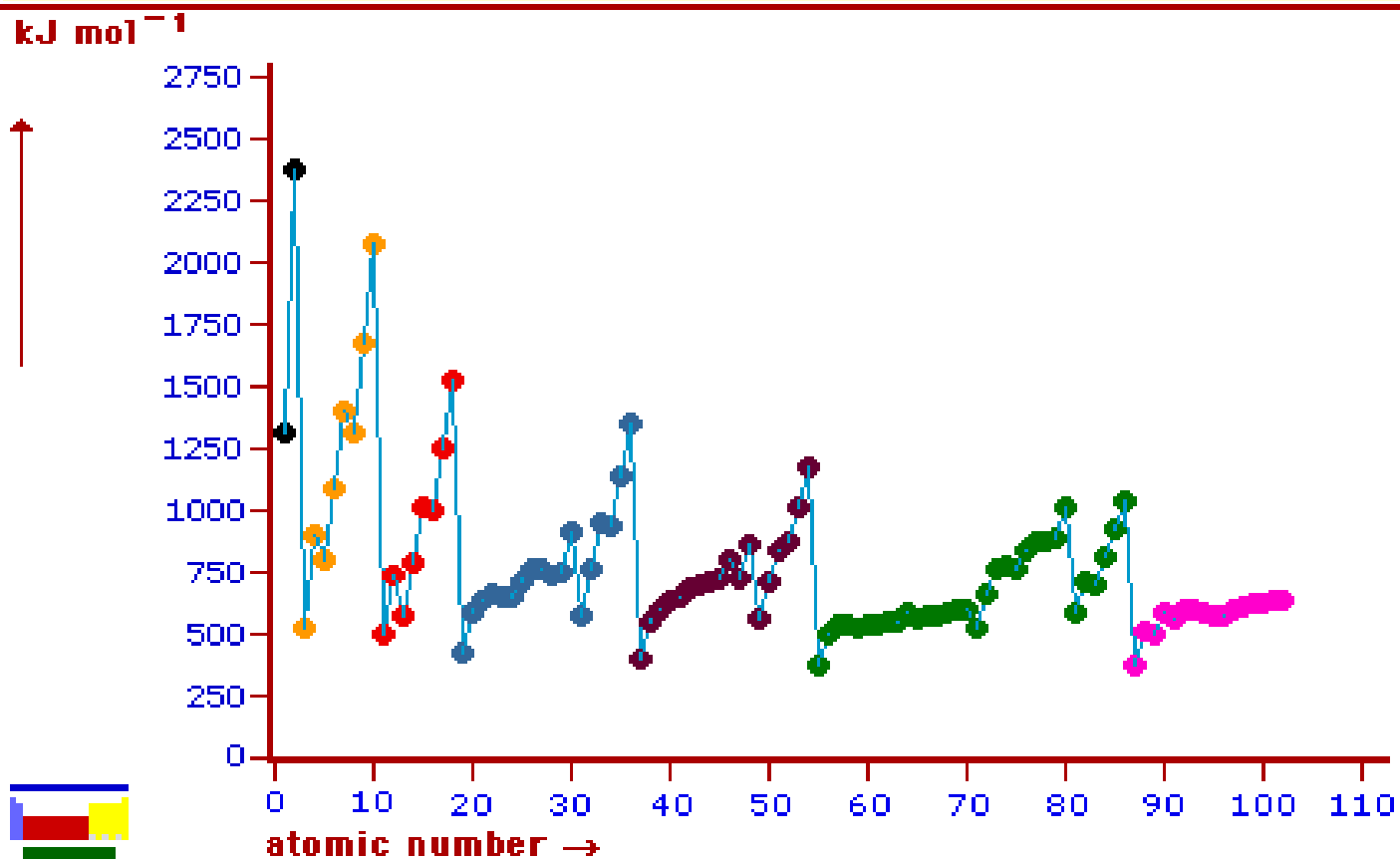
- As I increases, atoms are harder to ionize
- Successive ionizations for electrons are represented by I_i ($i = 1, 2, 3, \dots$)

$$I_1 < I_2 < I_3 < \dots$$

Ionization energy (I)

WebElements

Ionization enthalpy: 1st [kJ mol^{-1}] plotted against atomic number



Electron affinity

The electron affinity is the energy released when an electron is added to a gaseous neutral atom



- Unlike ionization, addition of an electron is usually favorable -even for electropositive elements

Periodicity and electron affinity

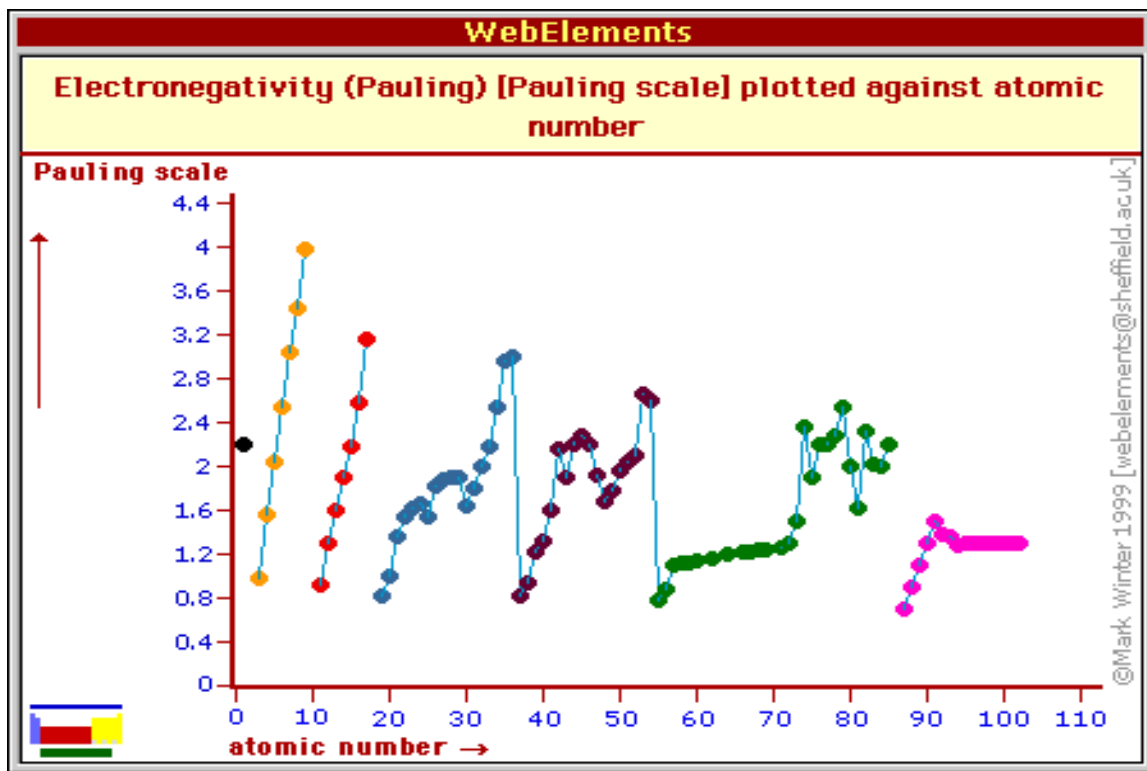
- Periodic but not smooth
- Affinity tends to be zero or positive when electron is added to new (Be, Mg, He, Ne etc) or half-filled (N) shell

H -73							He > 0
Li -60	Be > 0	B -27	C -122	N > 0	O -141	F -328	Ne > 0
Na -53	Mg > 0	Al -43	Si -134	P -72	S -200	Cl -349	Ar > 0
K -48	Ca -2	Ga -30	Ge -119	As -78	Se -195	Br -325	Kr > 0
Rb -47	Sr -5	In -30	Sn -107	Sb -103	Te -190	I -295	Xe > 0
1A	2A	3A	4A	5A	6A	7A	8A

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Electronegativity

- The tendency for an atom to attract electrons towards itself in a bond with another atom



What are Hard and Soft Acids and Bases?

Hard Acids and Bases

Hard acids consist of small highly charged cations and molecules in which a high positive charge can be induced on the central atom.

Examples of Hard Acids: H^+ , Li^+ , K^+ , Ca^{2+} , Al^{3+} , Sn^{4+} , BF_3 , BCl_3 , CO_2 , RCO^+ , SO_3 , RMgX , VO_2^+ , AlCl_3

Hard bases are highly electronegative and of low polarizability.

Examples of Hard Bases: F^- , OH^- , NH_3 , N_2H_4 , ROH , H_2O , SO_4^{2-} , PO_4^{3-}

Hard bases react more readily to form stable compounds and complexes with hard acids.

What are Hard and Soft Acids and Bases?

Soft Acids and Bases

Soft acids consist of large low charge cations and molecules with relatively high energy occupied molecular orbitals. Soft acids are readily polarizable.

Examples of Soft Acids: Cs^+ , Cu^+ , Au^+ , Pt^{2+} , Hg^+ , BH_3 , Br_2 , I_2 , RO^+ , quinones

Hard bases have low electronegativity and low polarizability.

Examples of Soft Bases: H^- , R^- , CO , PR_3 , C_6H_6 , SCN^-

Soft bases react more readily and form stable compounds and complexes with soft acids.

THANKS