THE PERIODIC CLASSIFICATION OF ELEMENTS

Construction Principle

K	$1s^2$			
L	$2s^2$	$2p^6$		
M	$3s^2$	$3p^6$	$3d^{10}$	
N	$4s^2$	$4p^6$	$4d^{10}$	$4f^{14}$
O	$5s^2$	$5p^6$	$5d^{10}$	$5f^{14}$
P	$6s^2$	$6p^6$	$6d^{10}$	
Q	$7s^2$	$7p^6$		
R				

A line always starts with s and always ends with p.We strictly follow Klechkowski's rule

$1s^1$	$1s^2$															
$2s^1$	$2s^2$											$2p^1$	$2p^2$	$2p^3$	$2p^4$	$2p^5$	$2p^6$
$3s^1$	$3s^2$											$3p^1$	$3p^2$	$3p^3$	$3p^4$	$3p^5$	$3p^6$
$4s^1$	$4s^2$	$3d^1$	$3d^2$	$3d^3$	$3d^4$	$3d^5$	$3d^6$	$3d^7$	$3d^8$	$3d^9$	$3d^{10}$	$4p^1$	$4p^2$	$4p^3$	$4p^4$	$4p^5$	$4p^6$
$5s^1$	$5s^2$	$4d^1$	$4d^2$	$4d^3$	$4d^4$	$4d^5$	$4d^6$	$4d^7$	$4d^8$	$4d^9$	$4d^{10}$	$5p^1$	$5p^2$	$5p^3$	$5p^4$	$5p^5$	$5p^6$
$6s^1$	$6s^2$	$5d^1$	$5d^2$	$5d^3$	$5d^4$	$5d^5$	$5d^6$	$5d^7$	$5d^8$	$5d^9$	$5d^{10}$	$6p^1$	$6p^2$	$6p^3$	$6p^4$	$6p^5$	$6p^6$
$7s^1$	$7s^2$	$6d^1$	$6d^2$	$6d^3$	$6d^4$	$6d^5$	$6d^6$	$6d^7$	$6d^8$	$6d^9$	$6d^{10}$	$7p^1$	$7p^2$	$7p^3$	$7p^4$	$7p^5$	$7p^6$

$4f^1$	$4f^2$	$4f^3$	$4f^4$	$4f^5$	$4f^6$	$4f^7$	$4f^8$	$4f^9$	$4f^{10}$	$4f^{11}$	$4f^{12}$	$4f^{13}$	$4f^{14}$
$5f^1$	$5f^2$	$5f^3$	$5f^4$	$5f^5$	$5f^6$	$5f^7$	$5f^8$	$5f^9$	$5f^{10}$	$5f^{11}$	$5f^{12}$	$5f^{13}$	$5f^{14}$

CLASSIFICATION AND ELECTRONIC CONFIGURATION

If we know the place in the classification, we immediately deduce the electronic configuration (and vice versa)

												13	14	15	16	17	18
$1s^1$	$1s^2$																
$2s^1$	$2s^2$											$2p^1$	$2p^2$	$2p^3$	$2p^4$	$2p^5$	$2p^6$
$3s^1$	$3s^2$	3	4	5	6	7	8	9	10	11	12	$3p^1$	$3p^2$	$3p^3$	$3p^4$	$3p^5$	$3p^6$
$4s^1$	$4s^2$	$3d^1$	$3d^2$	$3d^3$	$3d^4$	$3d^5$	$3d^6$	$3d^7$	$3d^8$	$3d^9$	$3d^{10}$	$4p^1$	$4p^2$	$4p^3$	$4p^4$	$4p^5$	$4p^6$
$5s^1$	$5s^2$	$4d^1$	$4d^2$	$4d^3$	$4d^4$	$4d^5$	$4d^6$	$4d^7$	$4d^8$	$4d^9$	$4d^{10}$	$5p^1$	$5p^2$	$5p^3$	$5p^4$	$5p^5$	$5p^6$
$6s^1$	$6s^2$	$5d^1$	$5d^2$	$5d^3$	$5d^4$	$5d^5$	$5d^6$	$5d^7$	$5d^8$	$5d^9$	$5d^{10}$	$6p^1$	$6p^2$	$6p^3$	$6p^4$	$6p^5$	$6p^6$
$7s^1$	$7s^2$	$6d^1$	$6d^2$	$6d^3$	$6d^4$	$6d^5$	$6d^6$	$6d^7$	$6d^8$	$6d^9$	$6d^{10}$	$7p^1$	$7p^2$	$7p^3$	$7p^4$	$7p^5$	$7p^6$

$4f^1$	$4f^2$	$4f^3$	$4f^4$	$4f^5$	$4f^6$	$4f^7$	$4f^8$	$4f^9$	$4f^{10}$	$4f^{11}$	$4f^{12}$	$4f^{13}$	$4f^{14}$
$5f^1$	$6f^2$	$6f^3$	$6f^4$	$6f^5$	$6f^6$	$6f^7$	$6f^8$	$6f^9$	$6f^{10}$	$6f^{11}$	$6f^{12}$	$6f^{13}$	$6f^{14}$

Exceptions to Klechkowski's rule: the element keeps its normal place

Example: Cu, Ag, Au $d^9\ s^2$ according to Klechkowski □ $d^{10}\ s^1$ real configuration still remain in column 11 and do not move to column 12

f-block: a d electron is placed before the f electrons appear

The different blocks of the Periodic Table

Block S

H	
Li	Be
Na	Mg
K	Ca
Rb	Sr
Cs	Ba
Fr	Ra

Block d

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Y	Sr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd
La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg
Ac									

Block p

					He
B	C	N	O	F	Ne
Al	Si	P	S	Cl	Ar
Ga	Ge	As	Se	Br	Kr
In	Sb	Se	Te	I	Xe
Tl	Pb	Bi	Po	At	Rn

Block f

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Di	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Em	Md	No	Lr

Case of Helium: Although belonging to the s block (1s2), it is placed in the p block (group of rare gases).

Element Families

Some families have been given special names to know.

Line = period

Column = family (or group)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Sr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Di	Ho	Er	Tm	Yb	Lu
Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Em	Md	No	Lr

Lanthanides

Actinides

1 : Alkaline

2 : Alkaline earth

16 : Chalcogens

17 : Halogens

18 : Rare Gases

Blocks d and f: transition elements

Block f = Rare earths

Sanderson's rule: An element is metallic if the number of electrons in its highest n shell is less than or equal to its period number. (except H and Ge)

Examples

Mg : Z = 12 = 10 + 2 $\Rightarrow$ (Ne) $3s^2$

2 electrons out of n=3 and belongs to period 3

2 < 3 $\Rightarrow$ Mg is a metal

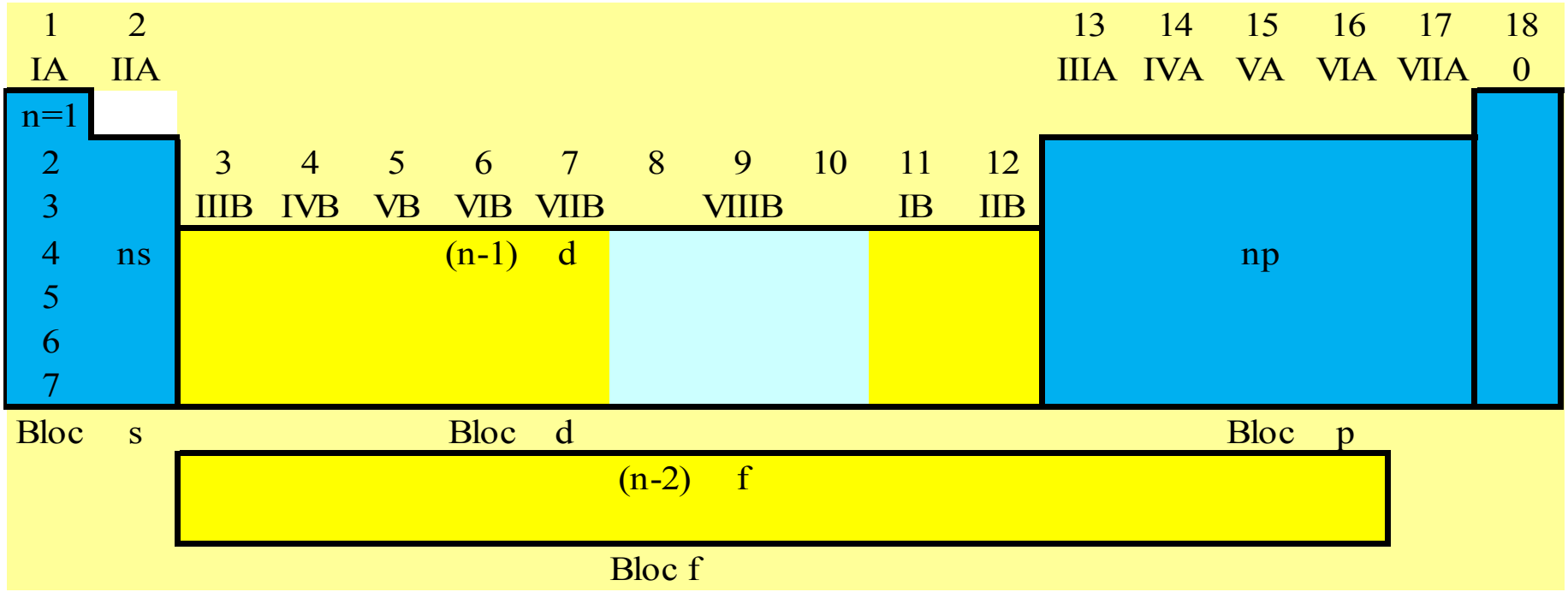
Ga : Z = 31 = 18 + 13 $\Rightarrow$ (Ar) $3d^{10}\ 4s^2\ 4p^1$

3 electrons out of n= 4 and belongs to period 4

3 < 4 $\Rightarrow$ Ga is a metal

1	H																He
2	Li	Be											B	C	N	O	F	Ne
3	Na	Mg											Al	Si	P	S	Cl	Ar
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
5	Rb	Sr	Y	Sr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
6	Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
7	Fr	Ra	Ac															

IN TERMS OF PERIODS - GROUPS AND SUBGROUPS



Group A: All elements of Block S and P

ns^{1-2} **Exp: (Ne) $3s^1$**

It ends with the s-c ns Group A s-g: IA

ns^2np^5

It ends with the s-c np Group A s-g: VIIA

Group B: All elements of Block d and f **$ns^2 (n-1)d^{1-10}$**

Exp: (Ar) $4s^2\ 3d^5$

It ends with the s-c of Group B⇒s-g: VIIB

(Ar) $4s^2\ 3d^9$ ⇒**St.R est** (Ar) $4s^1\ 3d^{10}$ ⇒**s-g IB**

Fe /(Ar) $4s^2\ 3d^6$ ⇒**s-g VIIIB**

Co /(Ar) $4s^2\ 3d^7$ ⇒**s-g VIIIB**

Ni /(Ar) $4s^2\ 3d^8$ ⇒**s-g VIIIB**

Lu : Z = 71 ⇒ (Xe) $6s^2\ 5d^1\ 4f^{14}$ ⇒s-g ????

Octet Rule:

An atom or ion that has an electronic structure similar to that of the rare gases in s2 p6 (i.e. 8 electrons = octet on its valence shell) will have particularly significant stability.

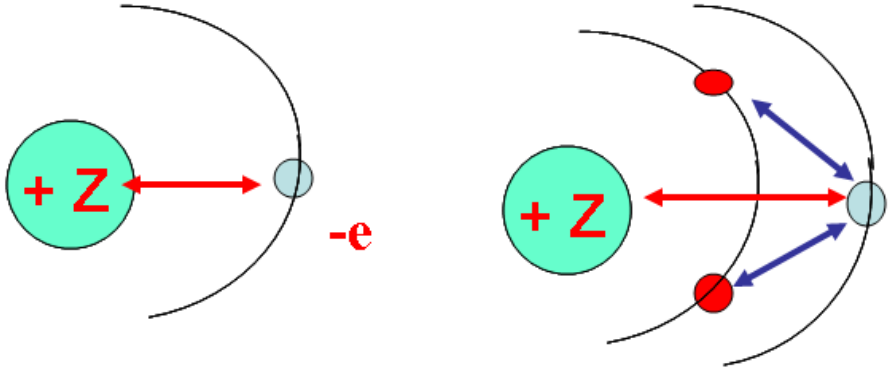
Ordinary atoms will therefore seek to acquire this s2 p6 structure in order to become more stable.

An atom seeks to acquire the electronic structure of the noble gas closest to it in the periodic table.

This rule makes it easy to predict the most stable ion of the s- and p-block elements.

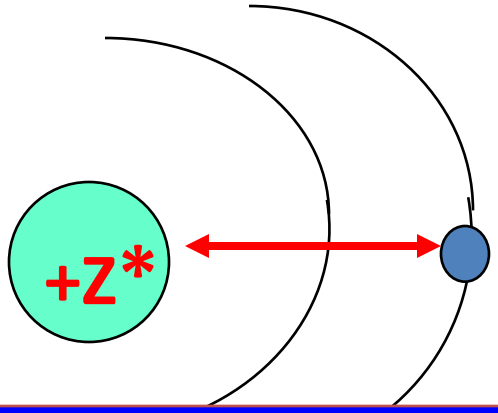
For elements too far from the noble gas structure (d and f blocks and column 14) this rule does not apply so simply.

SLATER'S RULES



Attraction and repulsion

Slater Model



"Corrected" Attraction

The other electrons act as a screen between the nucleus and the electron being studied.

The actual load Z is replaced by a hypothetical load Z*

Calculation of the effective nuclear charge Z*

To account for the repulsive effect of the other electrons, a hypothetical nuclear charge is calculated that is lower than the actual charge of the nucleus. This hypothetical charge is obtained by subtracting the screening effects of the other electrons from the actual Z:

$$Z^* = Z - \Sigma \sigma$$

σ = screen constant

Slater stated the rules that allow us to express these screening effects between electrons.

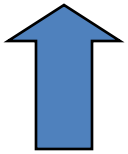
Summary

electrons tudied	Screening effects of other electrons					
	Internal group nj < ni -1	Group preceding nj = ni -1	Same group [s , p]	Same group [d]	Same group [f]	External groupnj > ni
[s , p]	1	0,85	0,35 (1s : 0,3)	0	0	0
[d]	1	1	1	0,35	0	0
[f]	1	1	1	1	0,35	0

Screening effect of electron j on electron i

1s	0,3										
2s2p	0,85	0,35									
3s3p	1	0,85	0,35								
3d	1	1	1	0,35							
4s4p	1	1	0,85	0,85	0,35						
4d	1	1	1	1	1	0,35					
4f	1	1	1	1	1	1	0,35				
5s5p	1	1	1	1	0,85	0,85	0,85	0,35			
5d	1	1	1	1	1	1	1	1	0,35		
5f	1	1	1	1	1	1	1	1	1	0,35	
6s6p	1	1	1	1	1	1	1	0,85	0,85	0,85	0,35
	1s	**2s2p**	**3s3p**	**3d**	**4s4p**	**4d**	**4f**	**5s5p**	**5d**	**5f**	**6s6p**

Button=> slide 10

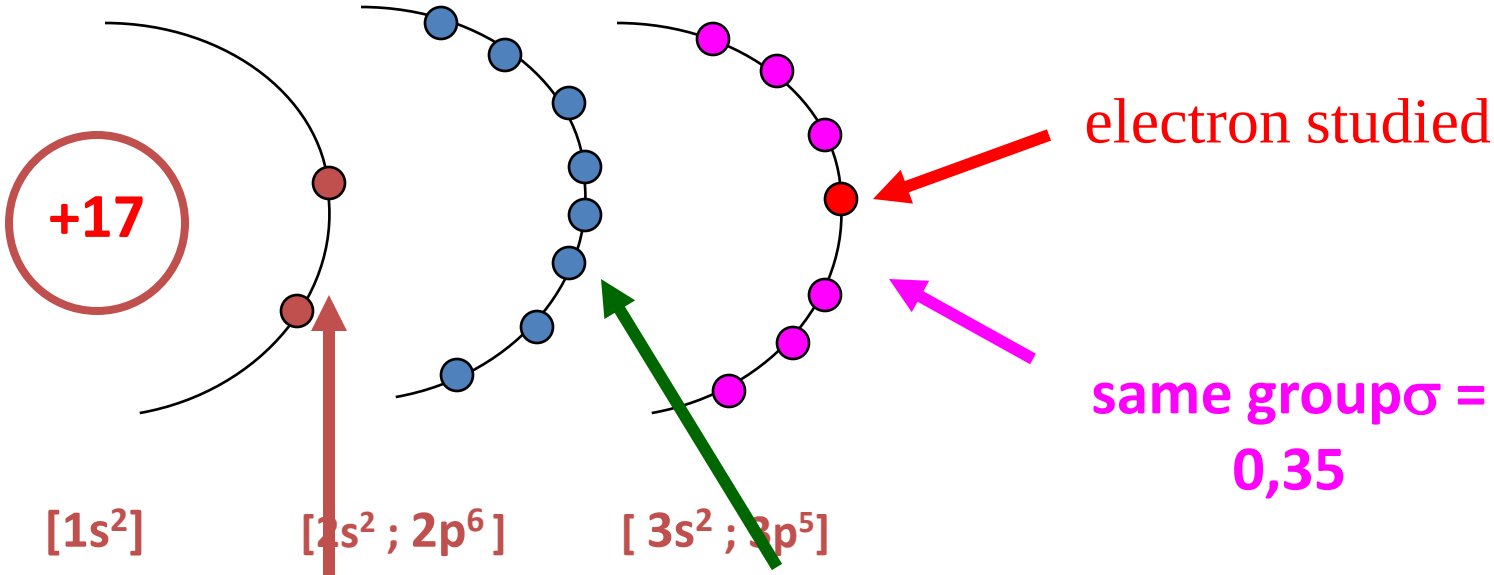


electron i

électron j

Examples

Cl : Z = 17 : $[1s^2]$; $[2s^2 ; 2p^6]$;$[3s^2 ; 3p^5]$



$$Z^* = 17 - (6 * 0.35) - (8 * 0,85) - (2 * 1) = 6,1$$

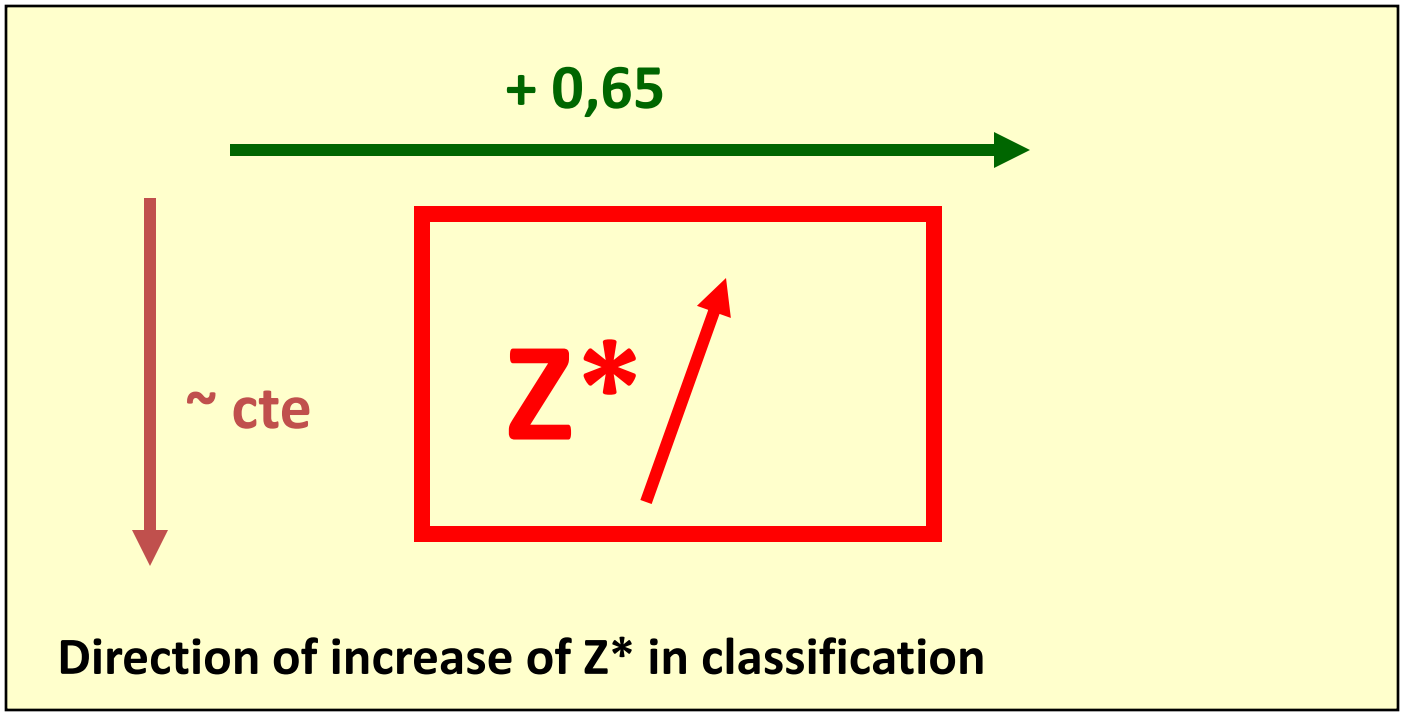
Z* values for a valence electron of s- and p-block elements

H							He
1							1,7
Li	Be	B	C	N	O	F	Ne
1,3	1,95	2,6	3,25	3,9	4,55	5,2	5,85
Na	Mg	Al	Si	P	S	Cl	Ar
2,2	2,85	3,5	4,15	4,8	5,45	6,1	6,75
K	Ca	Ga	Ge	As	Se	Br	Kr
2,2	2,85	5	5,65	6,3	6,95	7,6	8,25
Rb	Sr	In	Sn	Sb	Te	I	Xe
2,2	2,85	5	5,65	6,3	6,95	7,6	8,25

On the same column Z* increases slightly, then becomes constant when moving from top to bottom.

H	Li	Na	K	Rb
1	1,3	2,2	2,2	2,2

This variation being very small, we can neglect it as a first approximation.



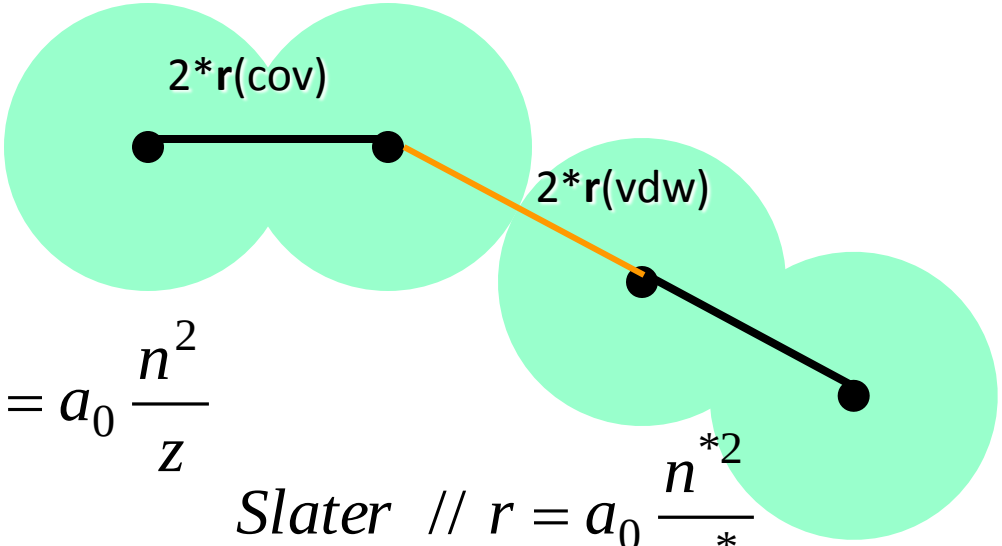
Direction of increase of Z* in classification

PROPERTIES OF ELEMENTS

The atomic radius

- **The covalence radius = half the distance between the nuclei of the corresponding simple body.**

- **The van der Waals radius = half of the smallest distance between two nuclei of different molecules**

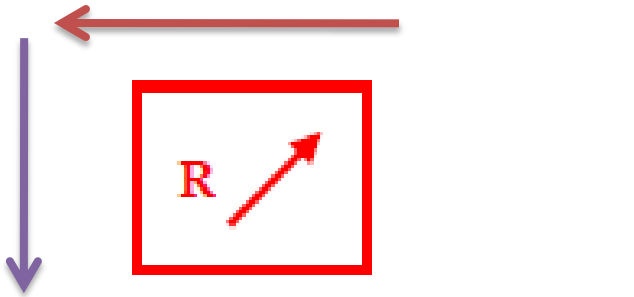


$$Bohr \;\; // \;\; r_n = a_0 \frac{n^2}{z}$$

$$Slater \;\; // \;\; r = a_0 \frac{n^{*2}}{Z^*}$$

with n* equal: 1 for n=1, 2 for n=2, 3 for n=3, 3.7 for n=4 and 4 for n=5 and 4.2 for n=6.

• On a line n is constant and Z* increases from left to right n*2/Z* will therefore decrease from left to right.

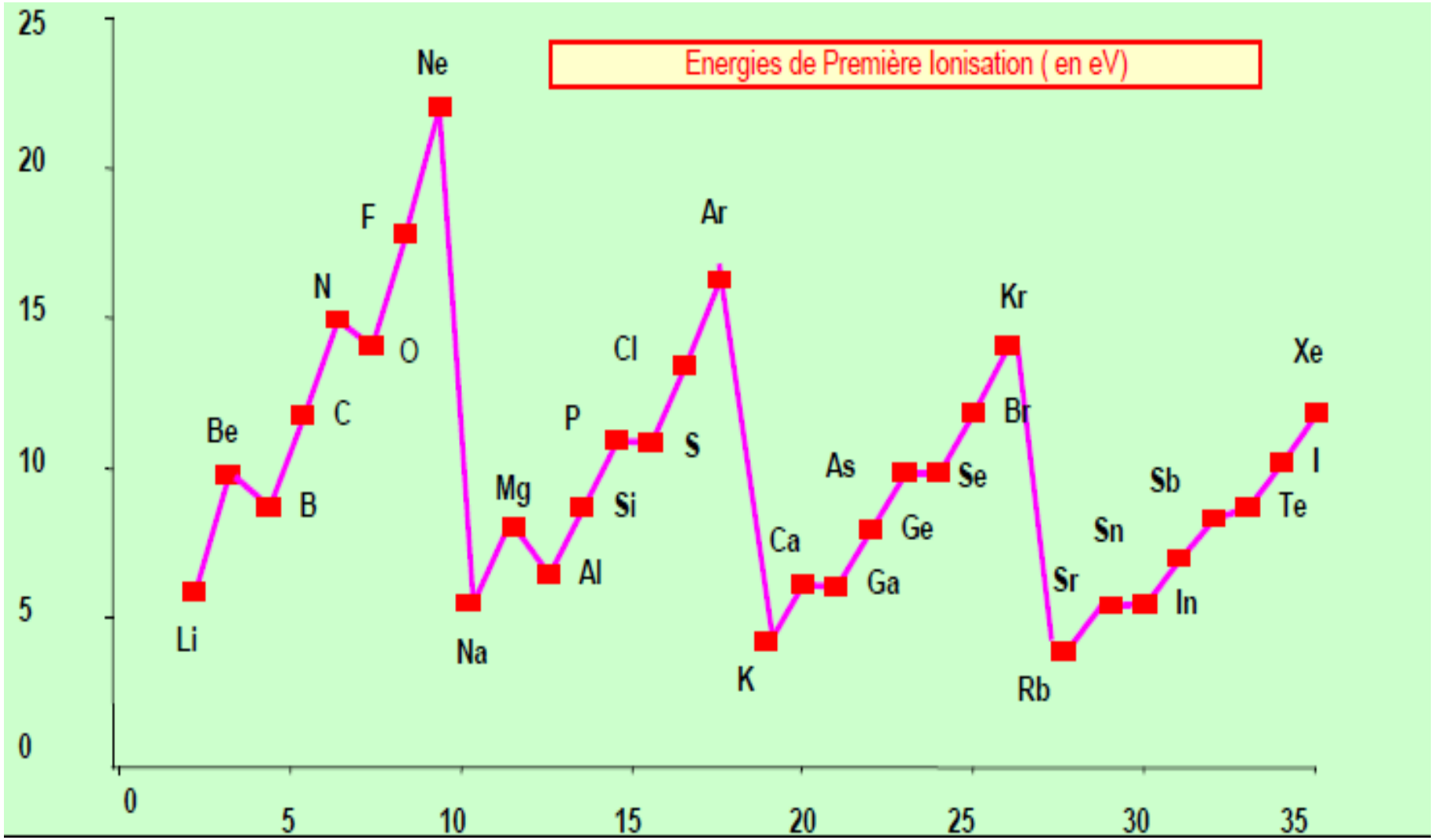


Sens d'augmentation
de R dans la classification

• On a column n increases from top to bottom, Z* increases very slightly from top to bottom (roughly constant).

• The effect of increasing n^2 far outweighs the increase in Z* and the atomic radius does indeed increase from top to bottom across a column of the periodic table.

Graph of ionization potential

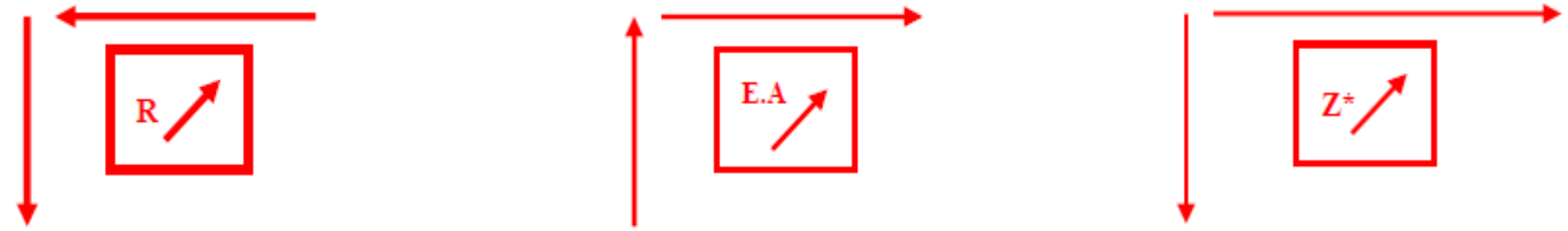


ELECTRONIC AFFINITY // AE

- **Electron affinity is the energy released when an electron is added to the atom.**

$A + e^- \rightarrow A^-$ $\mathbf{A_e}$(eV) $A^- + e^- \rightarrow A^{2-}$ $\mathbf{A_e'}$(eV)

H																	He
Li	Be											B	C	N	0	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru~	Rh~	Pd~	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Tu	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	Al	Rn
Fr	Ru	Ac*															
			Ce	Pr	Nd	Pm	Sm	Eu	Cd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th*	Pa*	U*	Np*	Pu	Am	Cm*	Bk	Cf	Es	Fm	Md	No	Lr	



Sens d'augmentation de $E.A_1$ dans la classification
L'électroaffinité varie comme l'énergie d'ionisation, en sens inverse du rayon atomique.

ELECTRONEGATIVITY

- ***Electronegativity characterizes the tendency of an atom to attract electrons to itself. It is an intuitive notion widely used by chemists to predict certain atomic or molecular properties.***

- There is no very precise definition of electronegativity.

- ***Three different scales are used to measure this tendency of atoms to attract electrons more or less strongly. Electronegativity will be expressed without units***

1. Pauling scale

$$(\Delta X)^2 = E_{AB} - \sqrt{E_{AA} * E_{BB}}\ .$$

EAB , EAA et EBB are the bond energies A-B, A-A and B-B expressed in Ev.

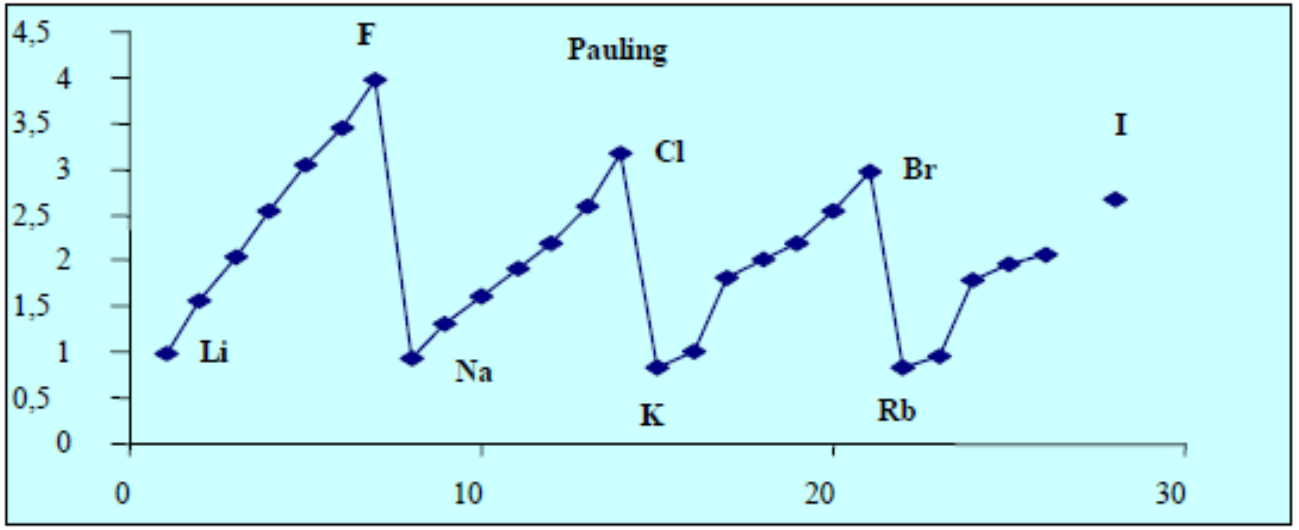
2. Mulliken scale

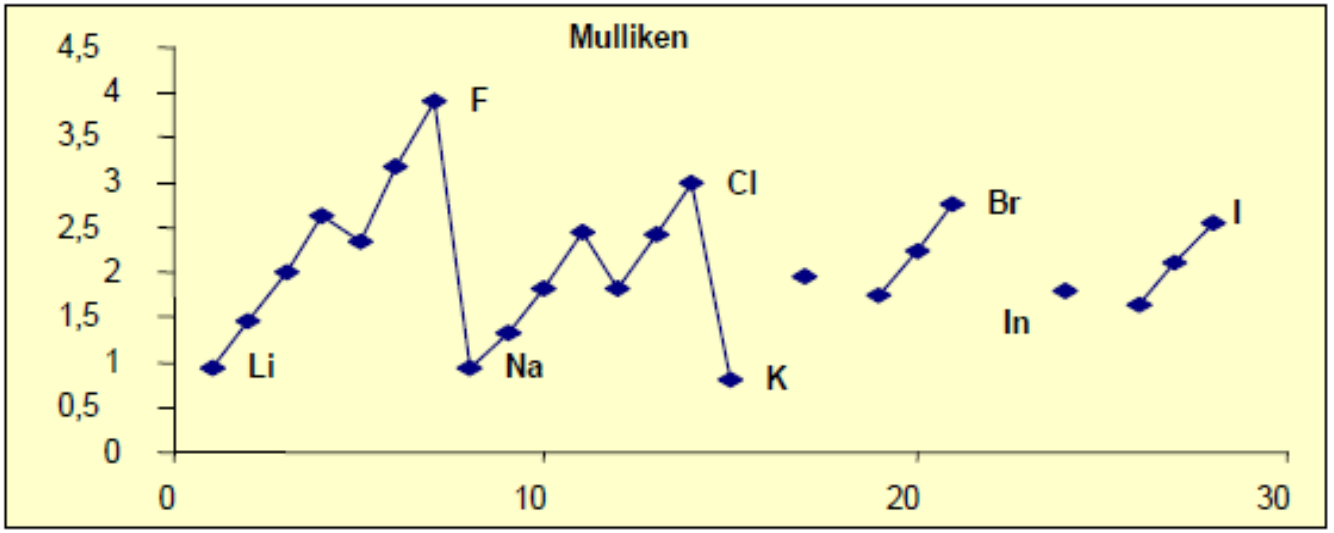
$$X_M = \frac{1}{2}(E.I_1 + E.A)$$

- For this scale to give values of the same order of magnitude as that of Pauling

$$X_M = 0.21(E.I_1 + E.A)\ .$$

	Pauling	Mulliken
Li	0,98	0,94
Be	1,57	1,46
B	2,04	2,01
C	2,55	2,63
N	3,04	2,33
O	3,44	3,17
F	3,98	3,91
Na	0,93	0,93
Mg	1,31	1,32
Al	1,61	1,81
Si	1,9	2,44
P	2,19	1,81
S	2,58	2,41
Cl	3,16	3
K	0,82	0,8
Ca	1	
Ga	1,81	1,95
Ge	2,01	
As	2,18	1,75
Se	2,55	2,23
Br	2,96	2,76
Rb	0,82	
Sr	0,95	
In	1,78	1,8
Sn	1,96	
Sb	2,05	1,65
Te		2,1
I	2,66	2,56





•Discontinuities in the Mulliken scale correspond to elements for which the electron affinity is unknown.