Periodic Trends - There are patterns that hold true for the elements of the periodic table

① Ionization Energy
② Electron Affinity
③ Electronegativity
④ Atomic Radii
⑤ Metallic Character

~~Memorize Trends~~

Ionization Energy (IE) - Also known as Ionization potential

IE is the energy required to remove an e^- from a gaseous species

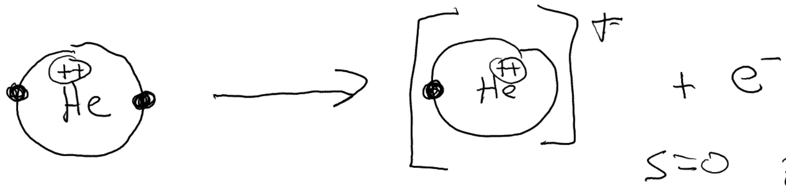
$$A^{n}_{(g)} \longrightarrow A^{n+1}_{(g)} + e^-$$

$IE = \Delta U$ (Internal Energy)

Always Endothermic for cases where n is non-negative.

Although not rigorously true $IE = \Delta U \approx \Delta H$

$$\boxed{\Delta U = \underbrace{\Delta H}_{\text{Enthalpy}} - \underbrace{P\Delta V}_{\text{work term}}}$$



$S > 0$
$Z^* < Z$

$S = 0$ $Z^* = Z$

1s orbital gets smaller

$P\Delta V \approx 0$

$\Delta U \approx \Delta H$

Helpful approximation for Born-Haber Cycles

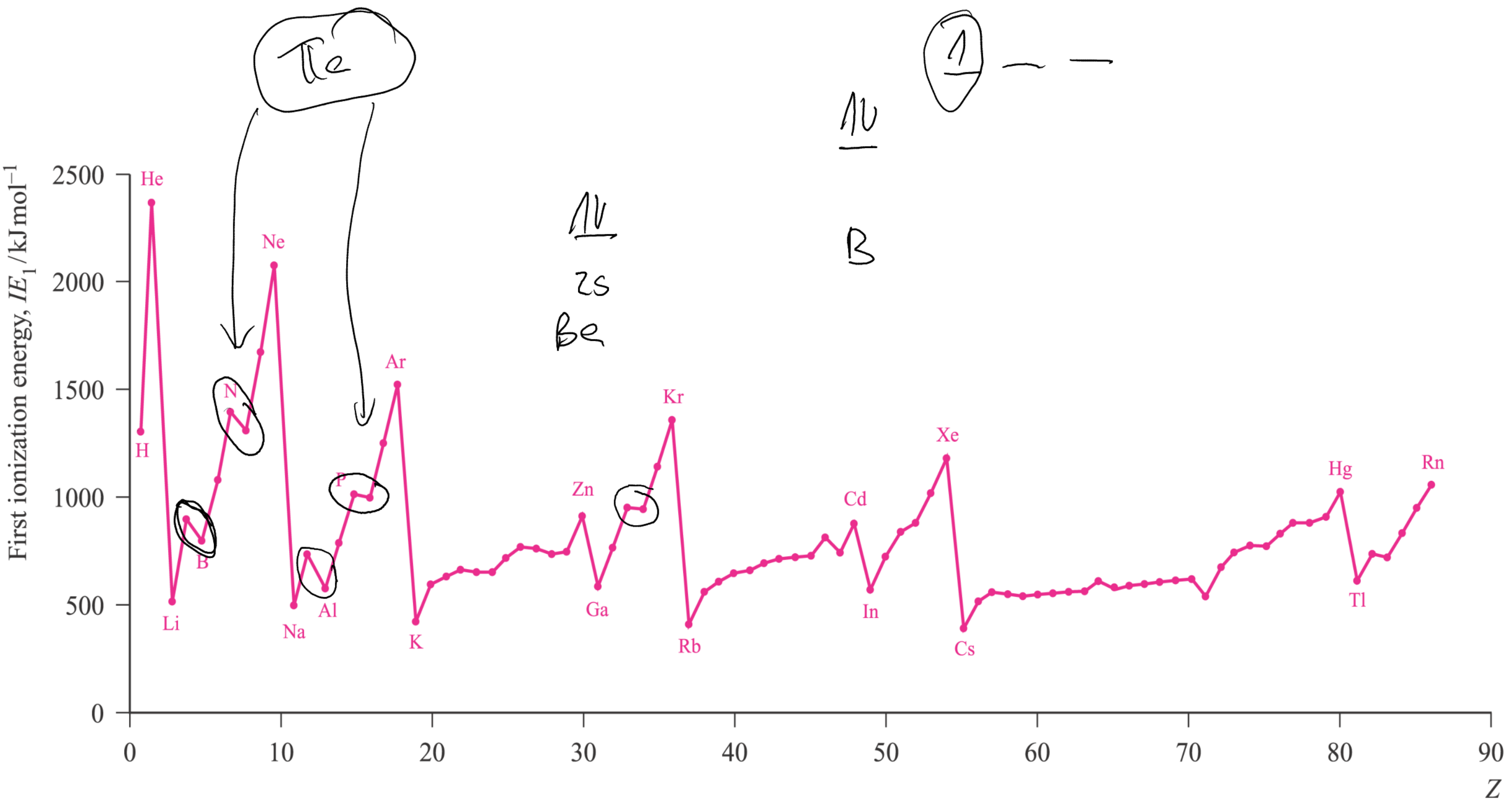
Z^* ↑ effective nuclear charge $= Z - S$

$$\boxed{Z^* = Z - S}$$

***s*-block elements**		***d*-block elements**										***p*-block elements**					
Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
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
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
55 Cs	56 Ba	57–71 La–Lu	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
87 Fr	88 Ra	89–103 Ac–Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub						

***f*-block elements**

Lanthanoids	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
Actinoids	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



① Noble gases have highest IEs for its given period

↳ As we go down a coloumn IEs decrease

② Alkali Metals have the lowest IEs for a given period.

③ Generally IEs increase accross a period

④ There's a discontinuity on going from groups 15→16 + from 12→13

⑤ Variation accross each row of d-block is flat.

$\boxed{Z^{*} = Z - S}$

Nobel Gas: $ns^2 np^6 \xrightarrow{e^-} ns^2 np^5$

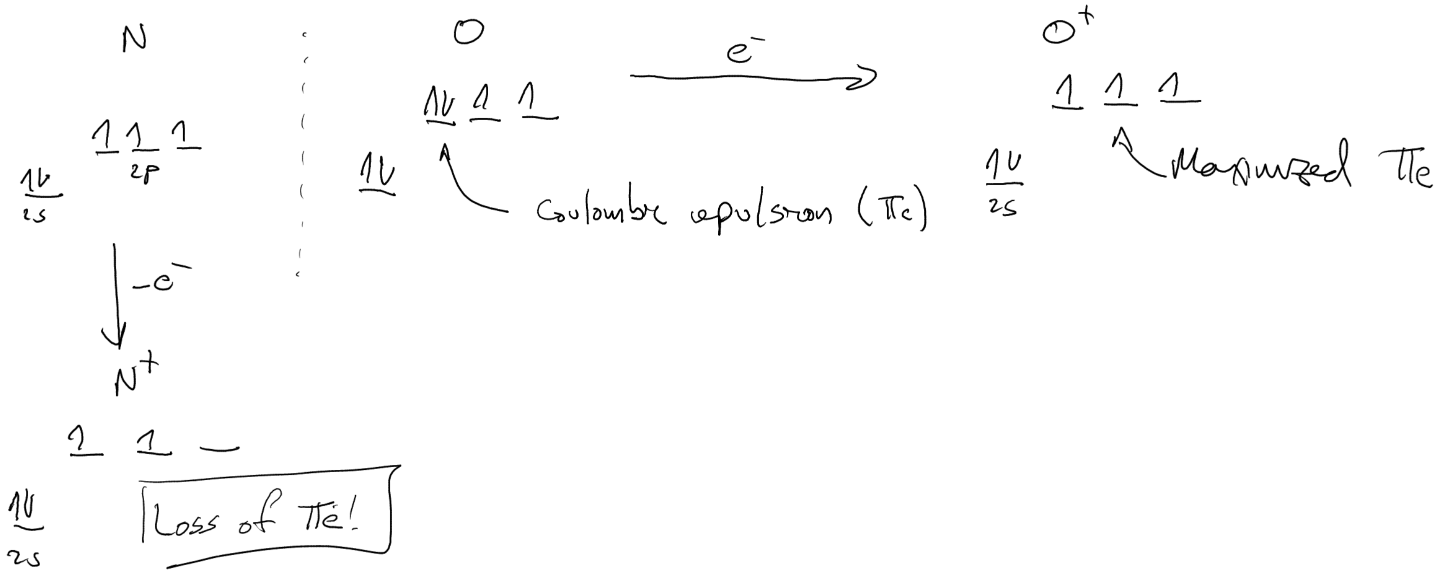
Hard to ionize because valence p electrons don't shield well

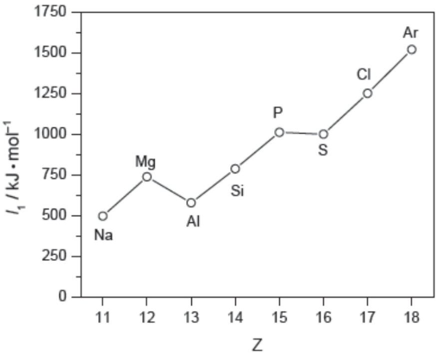
Alkali Metal ns^1

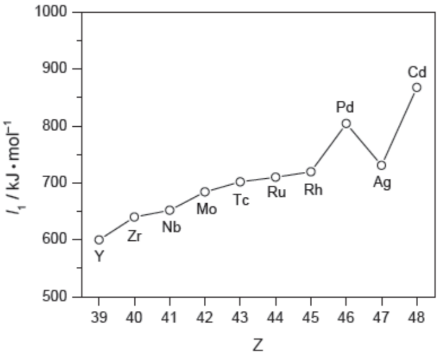
Easy to ionize core e^-'s shield effectively

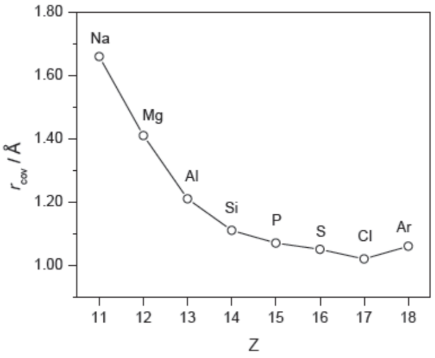
Diffusivity of valence orbital

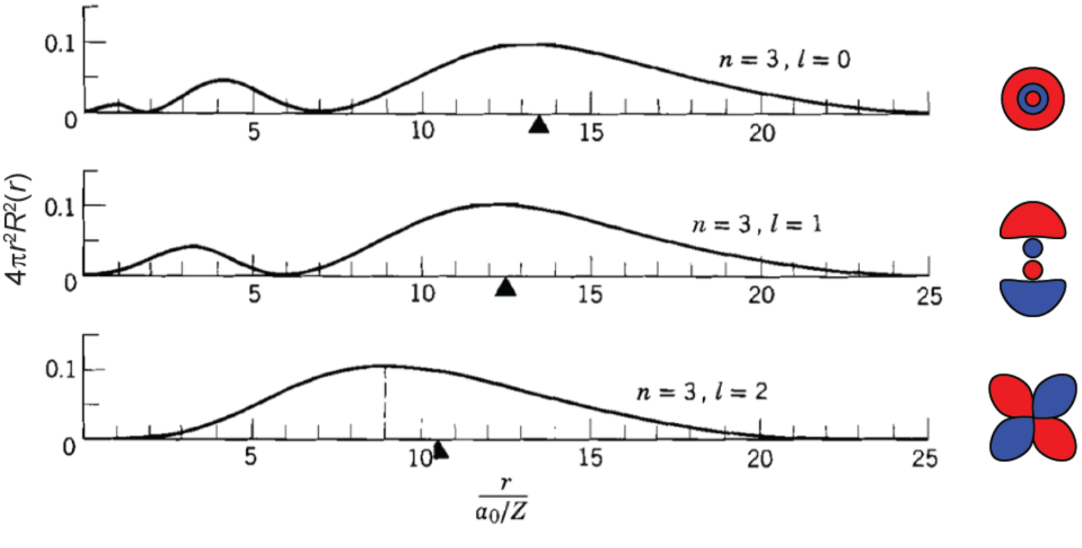
↳ Large or more diffuse the valence orbital the lower the IE will be




I_1 / kJ • mol^{-1}
1750
1500
1250
1000
750
500
250
0
Na
Mg
Al
Si
P
S
Cl
Ar
11
12
13
14
15
16
17
18
Z


I_1 / kJ • mol^{-1}
1000
900
800
700
600
500
Y
Zr
Nb
Mo
Tc
Ru
Rh
Pd
Ag
Cd
39
40
41
42
43
44
45
46
47
48
Z


r_{cov} / Å
1.80
1.60
1.40
1.20
1.00
Na
Mg
Al
Si
P
S
Cl
Ar
11
12
13
14
15
16
17
18
Z

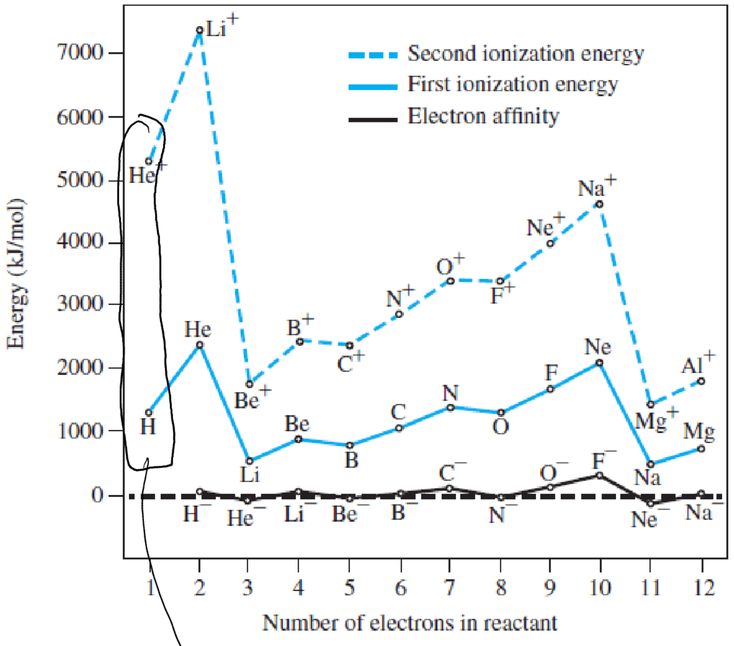

$4\pi r^2 R^2(r)$
0.1
0
$n = 3, l = 0$
$n = 3, l = 1$
$n = 3, l = 2$
5
10
15
20
25
$\frac{r}{a_0/Z}$

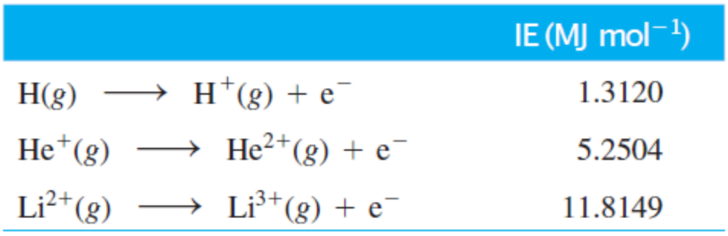
The more highly charged A^n species is the higher the expected IE

$$A^n_{(g)} \xrightarrow{e^-} A^{n+1}_{(g)} \xrightarrow{e^-} A^{n+2}_{(g)}$$

IE_1 IE_2

$IE_2 > IE_1$





	IE (MJ mol^{-1})
$H(g) \longrightarrow H^+(g) + e^-$	1.3120
$He^+(g) \longrightarrow He^{2+}(g) + e^-$	5.2504
$Li^{2+}(g) \longrightarrow Li^{3+}(g) + e^-$	11.8149

All $1e^-$ systems

Electron Affinity - Zeroth IE

$IE = \Delta U$

IE_1 : $A^\circ_{(g)} \rightarrow A^+_{(g)} + e^-$ $\boxed{\Delta U}$

$EA = -\Delta U$

$EA = IE_0$ $A^-_{(g)} \rightarrow A^\circ_{(g)} + e^-$

$-\Delta U$

Trends for EA are similar to that for IE

Exp. vs. Calc IEs

dashed lines
↳ exp
solid lines
↳ calc.

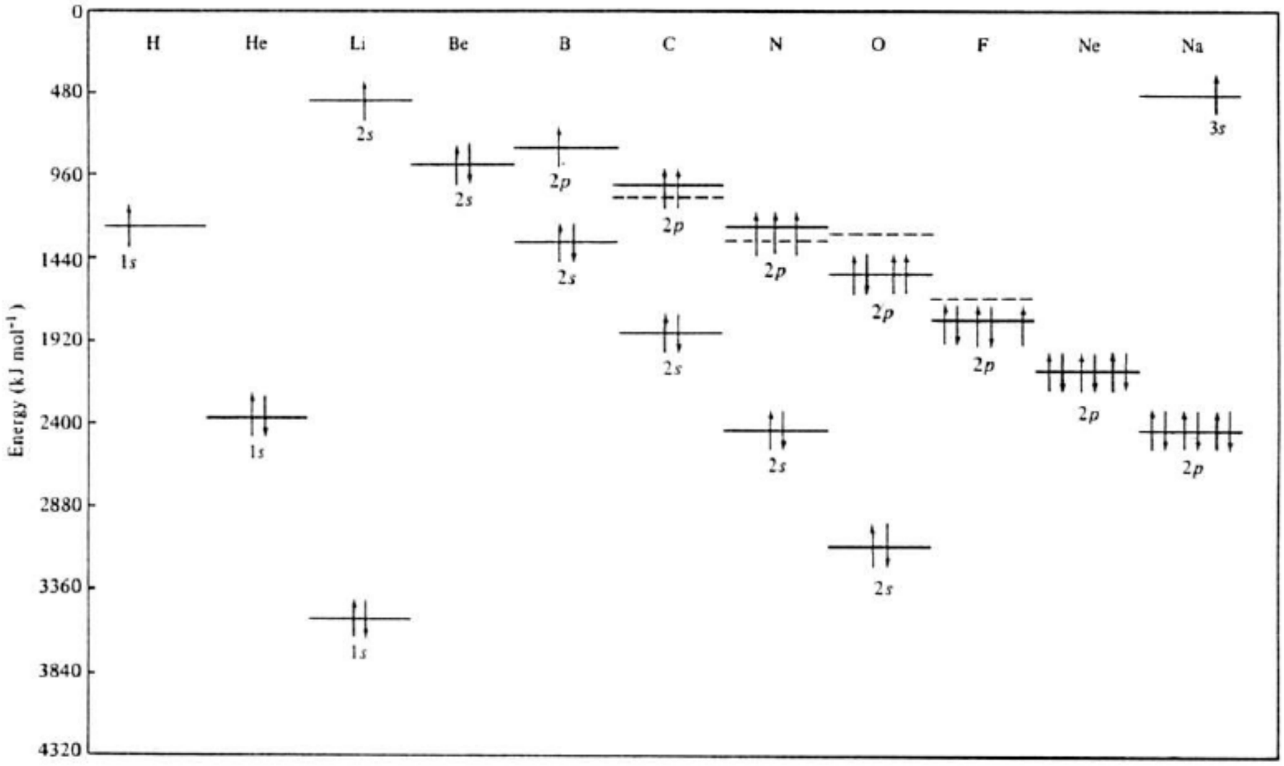


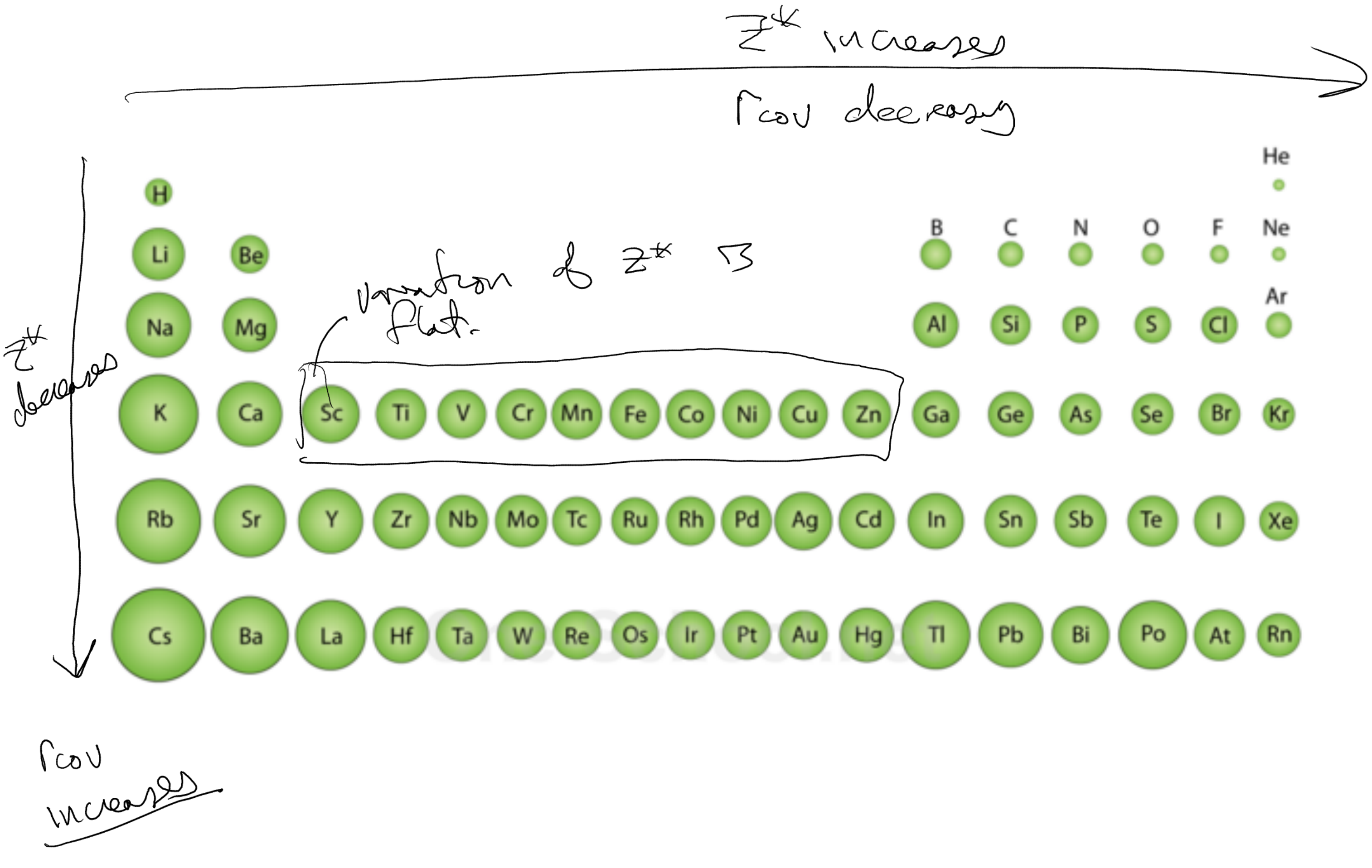
Fig. 2.12 Relative orbital energies of the elements hydrogen to sodium. Solid lines indicate *one-electron orbital energies*. Dashed lines represent experimental ionization energies, which differ as a result of electron–electron interactions.

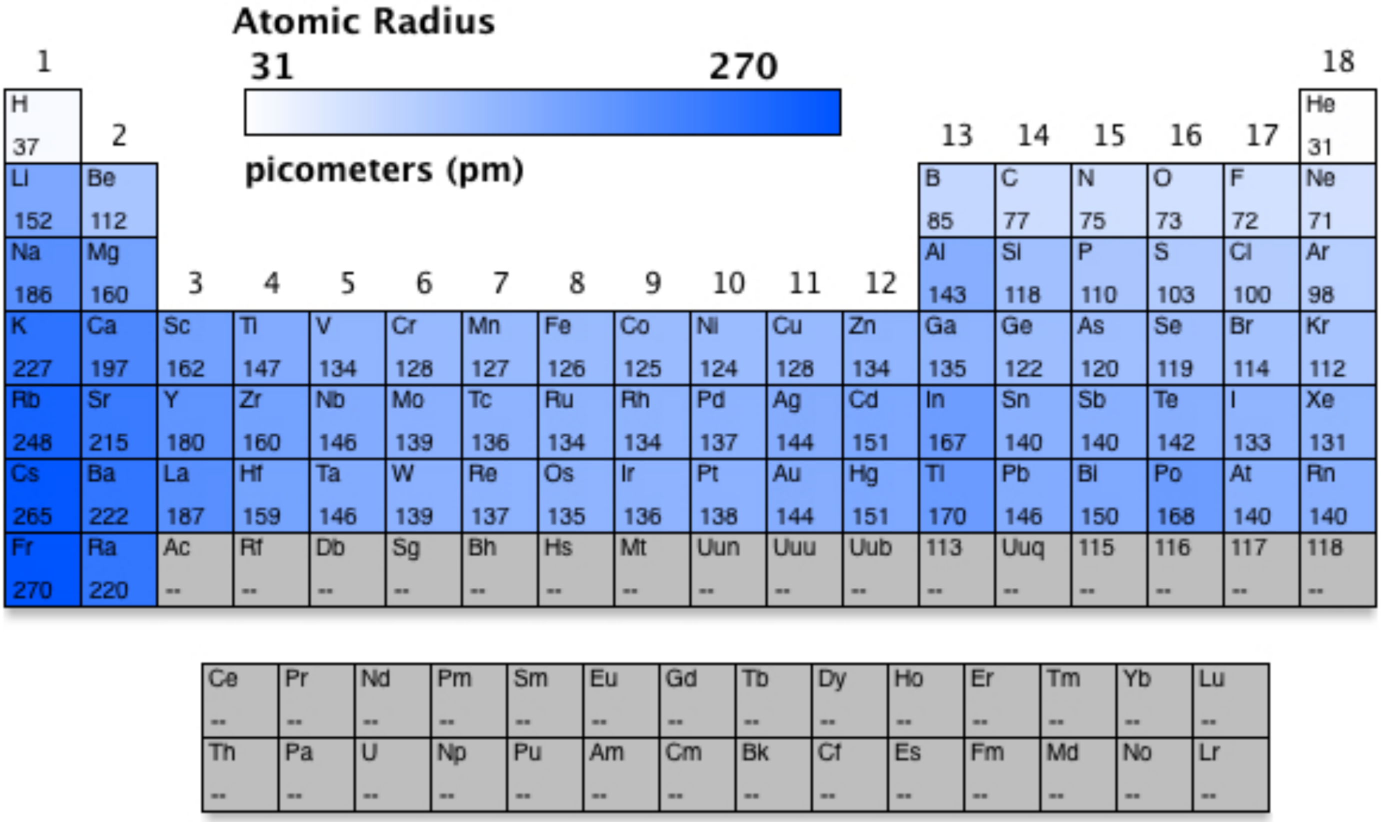
Atomic Radii

— Sizes of atoms are related to IE + EA

↳ All track Z^*

As Z^* ↑ e^- get pulled closer to nucleus + r_{cov} ↓





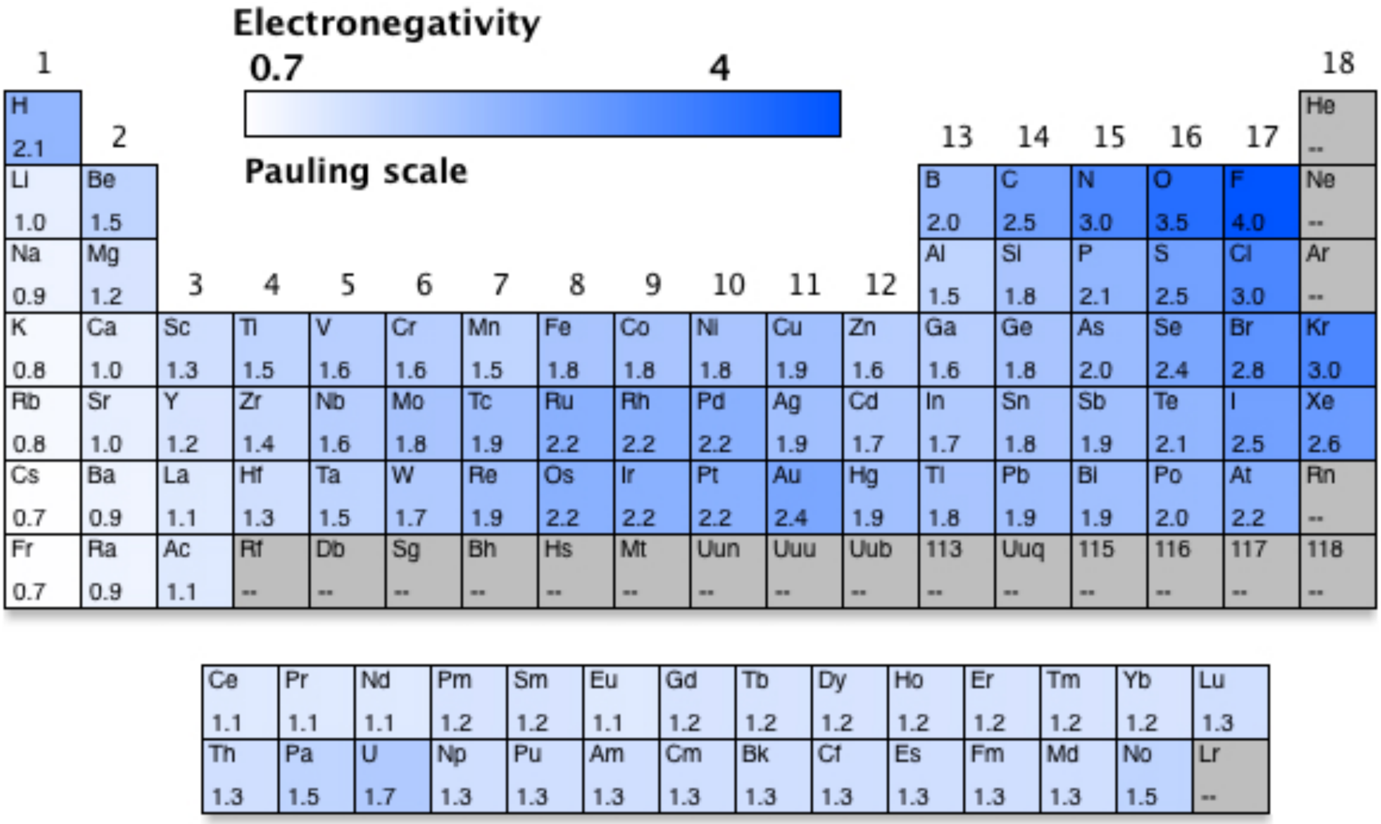
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 37																	He 31
Li 152	Be 112											B 85	C 77	N 75	O 73	F 72	Ne 71
Na 186	Mg 160											Al 143	Si 118	P 110	S 103	Cl 100	Ar 98
K 227	Ca 197	Sc 162	Ti 147	V 134	Cr 128	Mn 127	Fe 126	Co 125	Ni 124	Cu 128	Zn 134	Ga 135	Ge 122	As 120	Se 119	Br 114	Kr 112
Rb 248	Sr 215	Y 180	Zr 160	Nb 146	Mo 139	Tc 136	Ru 134	Rh 134	Pd 137	Ag 144	Cd 151	In 167	Sn 140	Sb 140	Te 142	I 133	Xe 131
Cs 265	Ba 222	La 187	Hf 159	Ta 146	W 139	Re 137	Os 135	Ir 136	Pt 138	Au 144	Hg 151	Tl 170	Pb 146	Bi 150	Po 168	At 140	Rn 140
Fr 270	Ra 220	Ac --	Rf --	Db --	Sg --	Bh --	Hs --	Mt --	Uun --	Uuu --	Uub --	113 --	Uuq --	115 --	116 --	117 --	118 --

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

Electronegativity – 1930s Linus Pauling

"Nature of the Chemical Bond"

* "The power of an atom to attract e^- to itself."



Electronegativity

0.7 – 4

Pauling scale

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 2.1																	He --
Li 1.0	Be 1.5											B 2.0	C 2.5	N 3.0	O 3.5	F 4.0	Ne --
Na 0.9	Mg 1.2											Al 1.5	Si 1.8	P 2.1	S 2.5	Cl 3.0	Ar --
K 0.8	Ca 1.0	Sc 1.3	Ti 1.5	V 1.6	Cr 1.6	Mn 1.5	Fe 1.8	Co 1.8	Ni 1.8	Cu 1.9	Zn 1.6	Ga 1.6	Ge 1.8	As 2.0	Se 2.4	Br 2.8	Kr 3.0
Rb 0.8	Sr 1.0	Y 1.2	Zr 1.4	Nb 1.6	Mo 1.8	Tc 1.9	Ru 2.2	Rh 2.2	Pd 2.2	Ag 1.9	Cd 1.7	In 1.7	Sn 1.8	Sb 1.9	Te 2.1	I 2.5	Xe 2.6
Cs 0.7	Ba 0.9	La 1.1	Hf 1.3	Ta 1.5	W 1.7	Re 1.9	Os 2.2	Ir 2.2	Pt 2.2	Au 2.4	Hg 1.9	Tl 1.8	Pb 1.9	Bi 1.9	Po 2.0	At 2.2	Rn --
Fr 0.7	Ra 0.9	Ac 1.1	Rf --	Db --	Sg --	Bh --	Hs --	Mt --	Uun --	Uuu --	Uub --	113 --	Uuq --	115 --	116 --	117 --	118 --

Ce 1.1	Pr 1.1	Nd 1.1	Pm 1.2	Sm 1.2	Eu 1.1	Gd 1.2	Tb 1.2	Dy 1.2	Ho 1.2	Er 1.2	Tm 1.2	Yb 1.2	Lu 1.3
Th 1.3	Pa 1.5	U 1.7	Np 1.3	Pu 1.3	Am 1.3	Cm 1.3	Bk 1.3	Cf 1.3	Es 1.3	Fm 1.3	Md 1.3	No 1.5	Lr --

(χ) Pauling Electronegativity (χ_p)

Electronegativity is a formalism distinct from IE or Eea

↳ Inferred from other properties

$\chi_p \Rightarrow$ Based Upon Bond Strengths (Difference in Bond Enthalpies

A — A

covalent

B — B

equal sharing of e^- (non-polar) → 0

$\overset{\delta-}{A} - \overset{\delta+}{B}$

$\longleftarrow\!\!\!+$

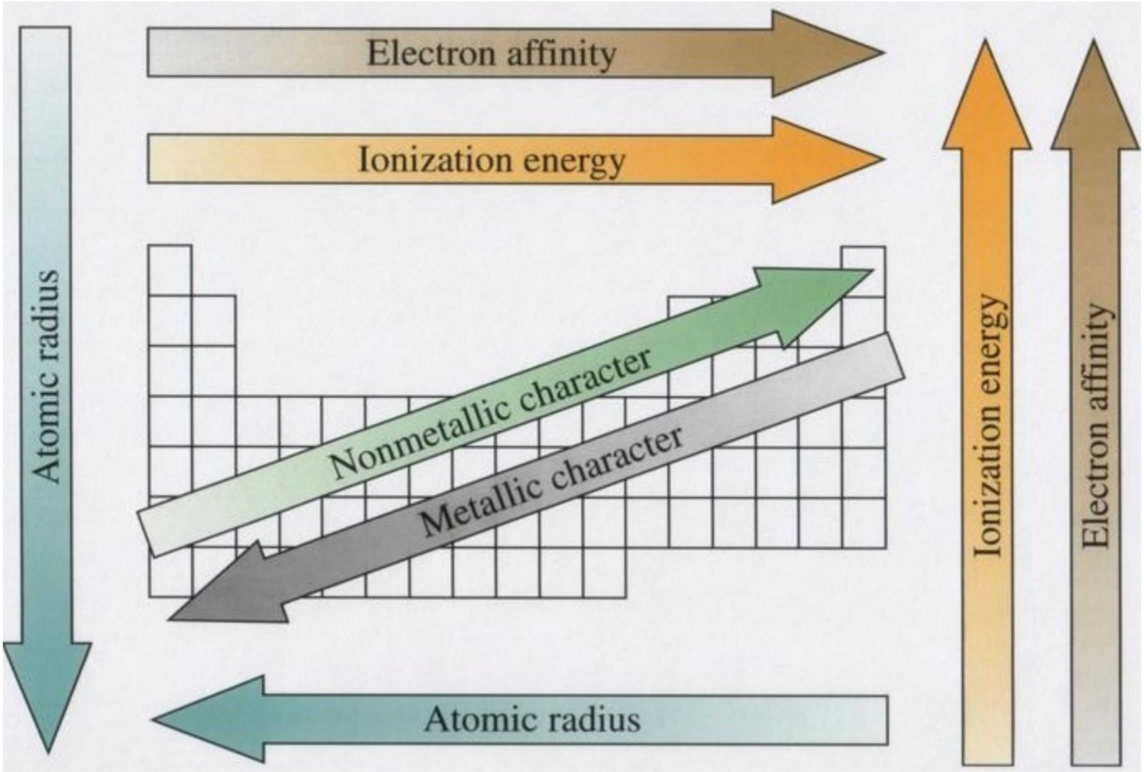
unequal sharing of e^- (polar)

$$BDE(A-B) = \frac{1}{2}\left[BDE(A-A) + BDE(B-B)\right]$$

$$BDE(\overset{+\!\!\longrightarrow}{Cl-F}) \neq \frac{1}{2}\left[BDE(Cl_2) + BDE(F_2)\right]$$

$\chi_F - \chi_{Cl}$ as $\sqrt{\dfrac{\Delta}{96.5\,\frac{kJ}{mol}}}$

$$\Delta = BDE(A-B) - \frac{1}{2}\left[BDE(A-A) + BDE(B-B)\right]$$


Electron affinity
Ionization energy
Atomic radius
Nonmetallic character
Metallic character
Ionization energy
Electron affinity
Atomic radius