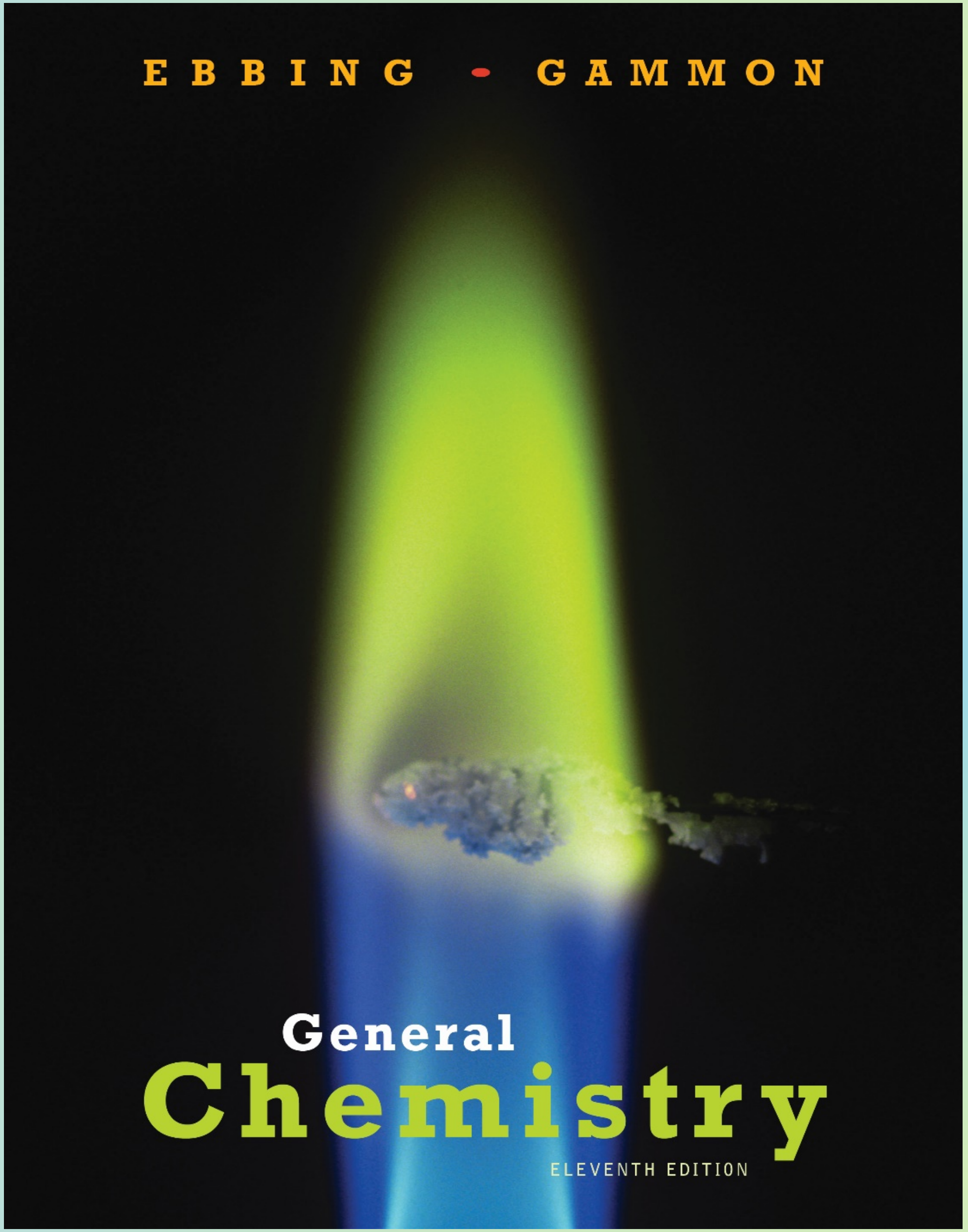


EBBING • GAMMON

General Chemistry

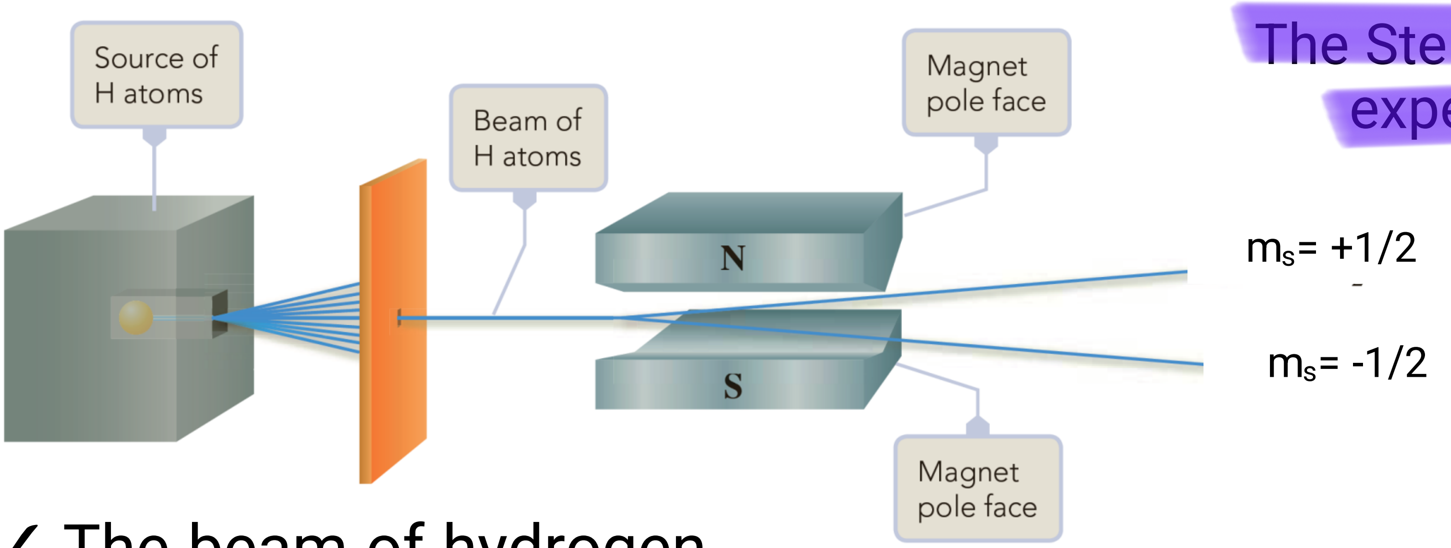
ELEVENTH EDITION

Electron Configurations and Periodicity

استبعاد

8.1 Electron Spin and the Pauli Exclusion Principle

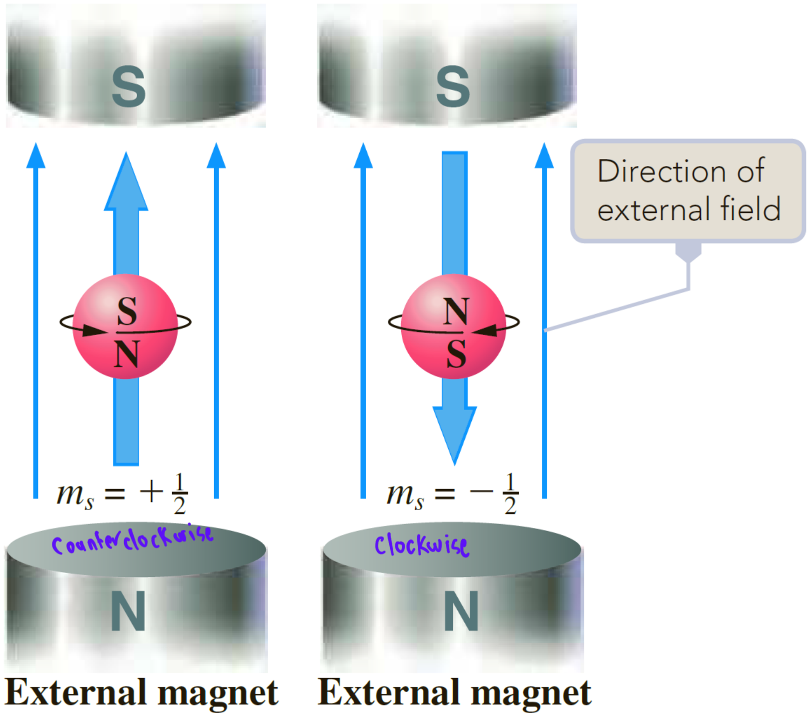
The Stern−Gerlach experiment



✓ The beam of hydrogen atoms is split into two by the magnetic field.

✓ Half of the atoms are bent in one direction and half in the other.

✓ The fact that the atoms are affected by the external magnet shows that they themselves act as magnets.



The four quantum numbers that could identify the third 3p

(a) $n=3, l=0, m=+1, s=+\frac{1}{2}$

(b) $n=2, l=2, m=-1, s=+\frac{1}{2}$

(c) $n=3, l=2, m=+1, s=-\frac{1}{2}$

(d) $n=3, l=1, m=-1, s=+\frac{1}{2}$

(d)

$n=3 \quad l=1$

$m_l=-1, 0, +1$

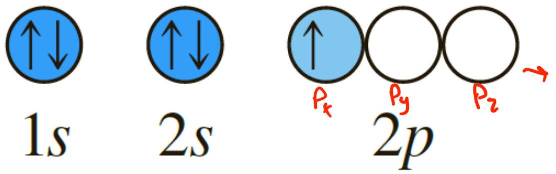
$m_s=\frac{1}{2}$ or $-\frac{1}{2}$

توزيع الإلكترونات على كل ال orbital

كيف بتوزع الإلكترون بال orbital الواحد (بـ s أو p ...)

➢ Electron Configurations and Orbital Diagrams

- ✓ An electron configuration of an atom is *a particular distribution of electrons among the available subshells.*
- ✓ A subshell consists of a group of orbitals having the same n and l quantum numbers but different m_l values.
- ✓ $_5B: 1s^2 2s^2 2p^1$
- ✓ An electron in an orbital is shown by an arrow; the arrow points up when m_s = +1/2 and down when m_s = -1/2.
- ✓ The orbital diagram of B is:



ما بتفرق
وين نحطه
لأنهم نفس
الطاقة

- ✓ **Pauli Exclusion Principle**

No two electrons in an atom can have the same four quantum numbers.

always differ in m_s quantum number

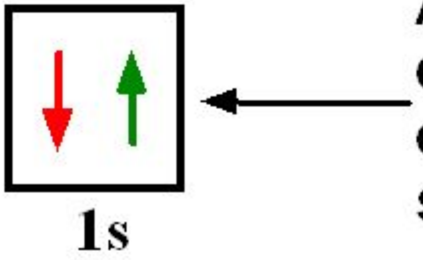
either $+\frac{1}{2}$ or $-\frac{1}{2}$

Writing Atomic Electron Configurations

Other is called the orbital box notation

ORBITAL BOX NOTATION
for He, atomic number = 2

$1s^2$



Arrows depict توصف بـ electron spin

One electron has $n = 1$, $l = 0$, $m_l = 0$, $m_s = + 1/2$

Other electron has $n = 1$, $l = 0$, $m_l = 0$, $m_s = - 1/2$

Quantum Numbers

What is one of the sets of quantum numbers for the 3d electrons in Fe?

n = 3; l = 2; m_l = +2; s = +1/2 or n = 3; l = 2; ml = +2; s = -1/2

or n = 3; l = 2; ml = +1; s = +1/2 or n = 3; l = 2; ml = +1; s = -1/2

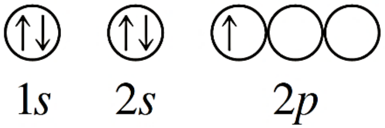
or n = 3; l = 2; ml = 0; s = +1/2 or n = 3; l = 2; ml = 0; s = -1/2

or n = 3; l = 2; ml = -1; s = +1/2 or n = 3; l = 2; ml = -1; s = -1/2

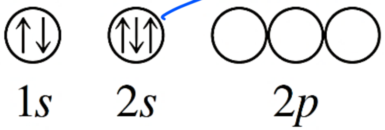
or n = 3; l = 2; ml = -2; s = +1/2 or n = 3; l = 2; ml = -2; s = -1/2

الاحتمالات

(Q) Which of the following orbital diagrams or electron configurations are possible and which are impossible, according to the Pauli exclusion principle? Explain

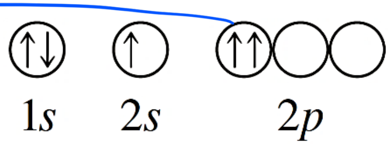
a.


✓

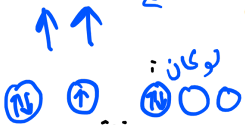
b.


✗

two electrons has the same quantum numbers

c.


✗



منعتبره صح على مبدأ باولي (بس هو خطأ) لأنه باولي ما إله دخل بال filling

d. $1s^3 2s^1$ ✗

× ↑↓↑

e. $1s^2 2s^1 2p^7$ ✗

⇅ ↑↓↓ ↑↓↑ ×

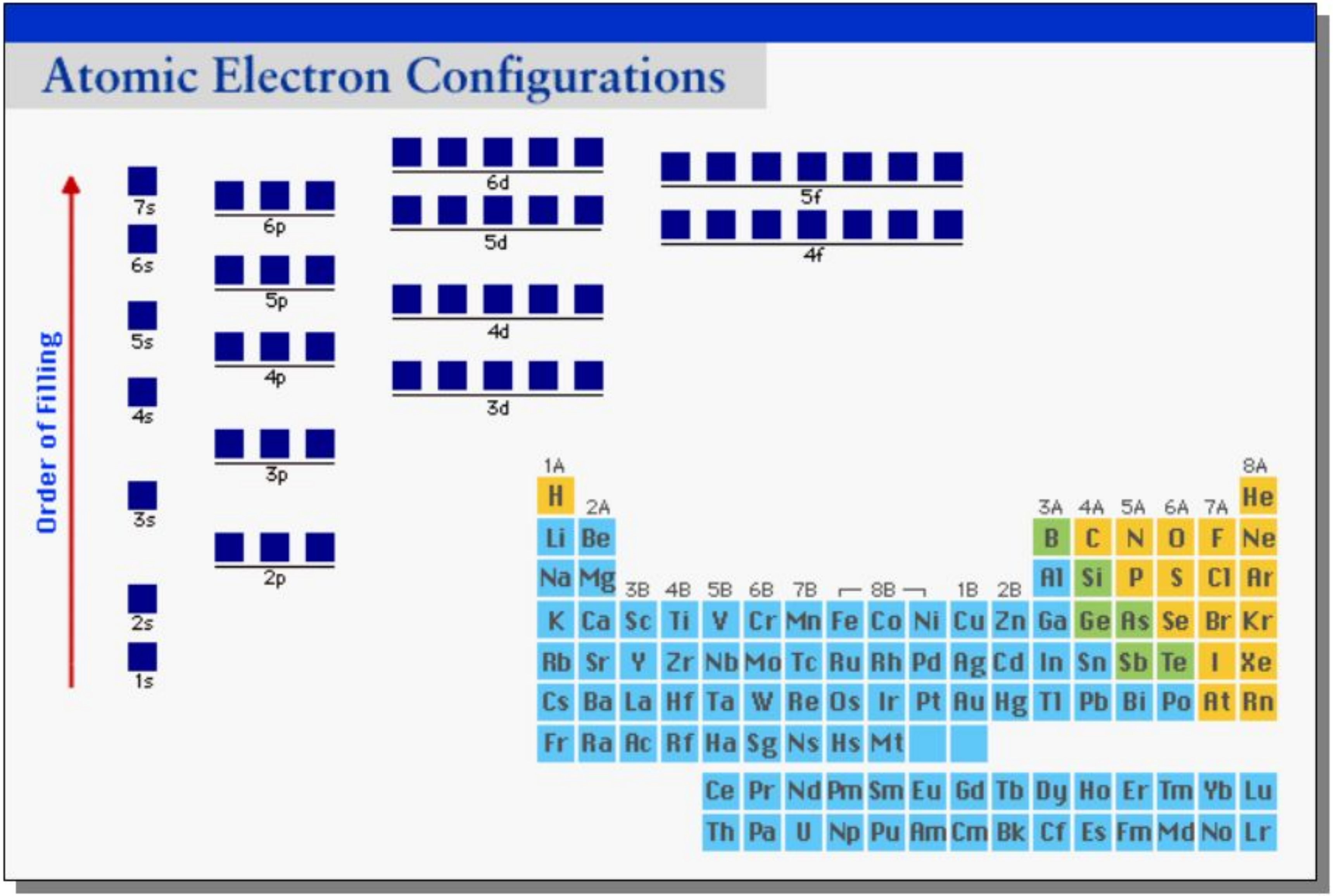
f. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ ✓

➢ Building-Up Principle (Aufbau Principle)

✓ *lowest energy orbitals are filled first* : 1s, then 2s, then 2p, then 3s, then 3p, etc.

✓ Following this principle, you obtain the electron configuration of an atom by successively filling subshells in the following order: 1*s*, 2*s*, 2*p*, 3*s*, 3*p*, **4*s***, **3*d***, 4*p*, **5*s***, **4*d***, 5*p*, 6*s*, 4*f*, 5*d*, 6*p*, 7*s*, 5*f*.

6d , 7P



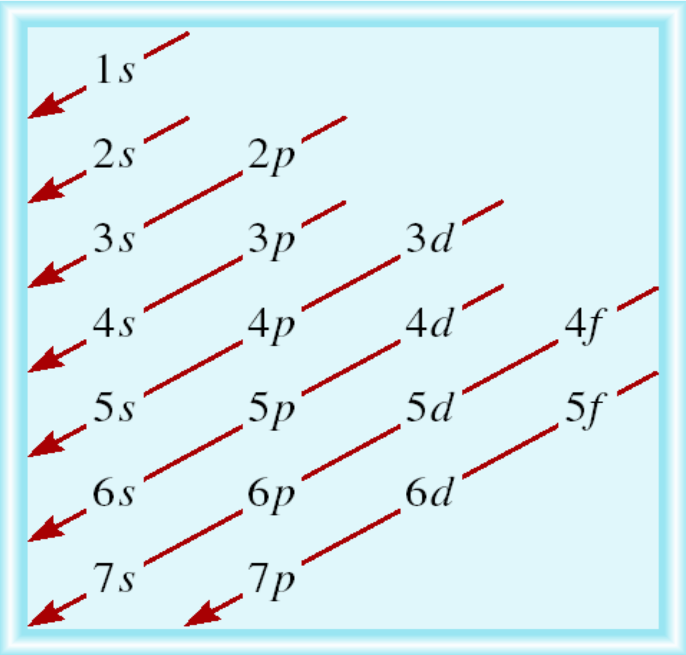
Atomic Electron Configurations

1A	2A	3B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
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	Zr	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	Rf	Ha	Sg	Ns	Hs	Mt									
				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

See "Toolbox" on CD for Electron Configuration tool.

➢ Electron Configurations and the Periodic Table

Order of orbitals (filling) in multi-electron atom



helium	$1s^2$
neon	$1s^2 2s^2 2p^6$
argon	$1s^2 2s^2 2p^6 3s^2 3p^6$
krypton	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

beryllium	$1s^2 2s^2$	or	[He]$2s^2$ n=1
magnesium	$1s^2 2s^2 2p^6 3s^2$	or	[Ne]$3s^2$ n=2
calcium	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	or	[Ar]$4s^2$ ↳ Ar n=3

boron	$1s^2 2s^2 2p^1$	or	[He]$2s^2 2p^1$
aluminium	$1s^2 2s^2 2p^6 3s^2 3p^1$	or	[Ne]$3s^2 3p^1$
gallium	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} \underbrace{4s^2 4p^1}_{\text{valence}}$	or	[Ar]$3d^{10} 4s^2 4p^1$ → ترتيب حسب n

✓ noble-gas core: *an inner-shell configuration corresponding to one of the noble gases.*

✓ valence electron: *An electron in an atom outside the noble-gas or pseudo-noble-gas core.* $(n-1)d^{10}$ الالكترونات الداخلية

(ال d يدخل بال valence electrons بال transition metal)

Main-Group Elements
s subshell fills

ولما يكون d ← full
منعتبره من ال core حتى لو كان
نوبل غاز ، كمان زي Zn , Cd مع
إنهم Transition

Valence electrons (S)

1 **H** $1s^1$	Atomic number Symbol Valence-shell configuration

Main-Group Elements
p subshell fills

Valence electrons s and P

Transition Metals
d subshell fills

d بنتهوا ب

Valence electron s and d

n=2

6-2=4

n-1 4-1=3

special case

special case

[illegible]

valence

5-1

Ga [Ar] $4s^2 3d^{10} 4p^1$

31

18

Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 **H** $1s^1$																	2 **He** $1s^2$
2	3 **Li** $2s^1$	4 **Be** $2s^2$											5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
3	11 **Na** $3s^1$	12 **Mg** $3s^2$											13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$
4	19 **K** $4s^1$	20 **Ca** $4s^2$	21 **Sc** $3d^14s^2$	22 **Ti** $3d^24s^2$	23 **V** $3d^34s^2$	24 **Cr** $3d^54s^1$	25 **Mn** $3d^54s^2$	26 **Fe** $3d^64s^2$	27 **Co** $3d^74s^2$	28 **Ni** $3d^84s^2$	29 **Cu** $3d^{10}4s^1$	30 **Zn** $3d^{10}4s^2$	31 **Ga** $4s^24p^1$	32 **Ge** $4s^24p^2$	33 **As** $4s^24p^3$	34 **Se** $4s^24p^4$	35 **Br** $4s^24p^5$	36 **Kr** $4s^24p^6$
5	37 **Rb** $5s^1$	38 **Sr** $5s^2$	39 **Y** $4d^15s^2$	40 **Zr** $4d^25s^2$	41 **Nb** $4d^45s^1$	42 **Mo** $4d^55s^1$	43 **Tc** $4d^55s^2$	44 **Ru** $4d^75s^1$	45 **Rh** $4d^85s^1$	46 **Pd** $4d^{10}$	47 **Ag** $4d^{10}5s^1$	48 **Cd** $4d^{10}5s^2$	49 **In** $5s^25p^1$	50 **Sn** $5s^25p^2$	51 **Sb** $5s^25p^3$	52 **Te** $5s^25p^4$	53 **I** $5s^25p^5$	54 **Xe** $5s^25p^6$
6	55 **Cs** $6s^1$	56 **Ba** $6s^2$	57-71 Lanthanides	72 **Hf** $5d^26s^2$	73 **Ta** $5d^36s^2$	74 **W** $5d^46s^2$	75 **Re** $5d^56s^2$	76 **Os** $5d^66s^2$	77 **Ir** $5d^76s^2$	78 **Pt** $5d^96s^1$	79 **Au** $5d^{10}6s^1$	80 **Hg** $5d^{10}6s^2$	81 **Tl** $6s^26p^1$	82 **Pb** $6s^26p^2$	83 **Bi** $6s^26p^3$	84 **Po** $6s^26p^4$	85 **At** $6s^26p^5$	86 **Rn** $6s^26p^6$
7	87 **Fr** $7s^1$	88 **Ra** $7s^2$	89-103 Actinides	104 **Rf** $6d^27s^2$	105 **Db** $6d^37s^2$	106 **Sg** $6d^47s^2$	107 **Bh** $6d^57s^2$	108 **Hs** $6d^67s^2$	109 **Mt** $6d^77s^2$	110 **Uun** $6d^87s^2$	111 **Rg** $6d^97s^2$	112 **Cn** $6d^{10}7s^2$	113 **Uut** $7s^27p^1$	114 **Uuq** $7s^27p^2$	115 **Uup** $7s^27p^3$	116 **Uuh** $7s^27p^4$	117 **Uus** $7s^27p^5$	118 **Uuo** $7s^27p^6$

Inner Transition Metals
f subshell fills

f بنتهوا ب

g

n-2 6-2=4

57 **La** $5d^16s^2$	58 **Ce** $4f^15d^16s^2$	59 **Pr** $4f^36s^2$	60 **Nd** $4f^46s^2$	61 **Pm** $4f^56s^2$	62 **Sm** $4f^66s^2$	63 **Eu** $4f^76s^2$	64 **Gd** $4f^75d^16s^2$	65 **Tb** $4f^96s^2$	66 **Dy** $4f^{10}6s^2$	67 **Ho** $4f^{11}6s^2$	68 **Er** $4f^{12}6s^2$	69 **Tm** $4f^{13}6s^2$	70 **Yb** $4f^{14}6s^2$	71 **Lu** $4f^{14}5d^16s^2$
89 **Ac** $6d^17s^2$	90 **Th** $6d^27s^2$	91 **Pa** $5f^26d^17s^2$	92 **U** $5f^36d^17s^2$	93 **Np** $5f^46d^17s^2$	94 **Pu** $5f^67s^2$	95 **Am** $5f^77s^2$	96 **Cm** $5f^76d^17s^2$	97 **Bk** $5f^97s^2$	98 **Cf** $5f^{10}7s^2$	99 **Es** $5f^{11}7s^2$	100 **Fm** $5f^{12}7s^2$	101 **Md** $5f^{13}7s^2$	102 **No** $5f^{14}7s^2$	103 **Lr** $5f^{14}7s^27p^1$

↳ valence electrons (S and f) ← يكون

🟧	Main-group elements
🟩	Transition metals
🟦	Inner transition metals

➢ Exceptions to the Building-Up Principle

Stable → امتلاء كلي أو نصفي

Not full   full

chromium (Cr)(Z =24): [Ar]$3d^4 4s^2$ expected

[Ar]$3d^5 4s^1$ experimental ✓

half full   half full → more stable

Not full   full

copper (Cu)(Z =29): [Ar]$3d^9 4s^2$ expected

[Ar]$3d^{10} 4s^1$ experimental ✓

full   half full

8.3 Writing Electron Configurations Using the Periodic Table

Kr(36): [Ar]$4s^2 3d^{10} 4p^6$ or [Ar]$3d^{10} 4s^2 4p^6$

Nb(41): ~~[Kr]$4s^2 3d^{10} 4p^6$~~

Sb(51): [Kr]$5s^2 4d^{10} 5p^3$

(Q) Use the building-up principle to obtain the configuration for the ground state of the gallium atom ($Z = 31$). Give the configuration in complete form (do not abbreviate for the core). What is the valence-shell configuration?

$1s^22s^22p^63s^23p^64s^23d^{10}4p^1$ → $\mathbf{1s^22s^22p^63s^23p^63d^{10}4s^24p^1}$

→ The valence-shell configuration is $4\mathbf{s}^24\mathbf{p}^1$

(Q) What are the configurations for the outer electrons of:

a. tellurium, $Z = 52$, and b. nickel, $Z = 28$?

Te : $[Kr]5s^24d^{10}5p^4$ → $[Kr]\ 4d^{10}\ 5s^25p^4$ → $5s^25p^4$

Ni : $[Ar]4s^23d^8$ → $4s^23d^8$

Exercise 8.4 The atom (X) has the ground-state configuration $[Xe]4f^{14}\ 5d^{10}6s^26p^2$. Find the period and group for this element. From its position in the periodic table, would you classify lead as a main-group element, a transition element, or an inner transition element? main Group

Period
n= 6

Group 4A

$$\underset{26}{Fe} : [Ar]\ \underbrace{4s^2\ 3d^6}_{\text{valence}}$$

→ لأنهم بشاركوا بالتفاعلات

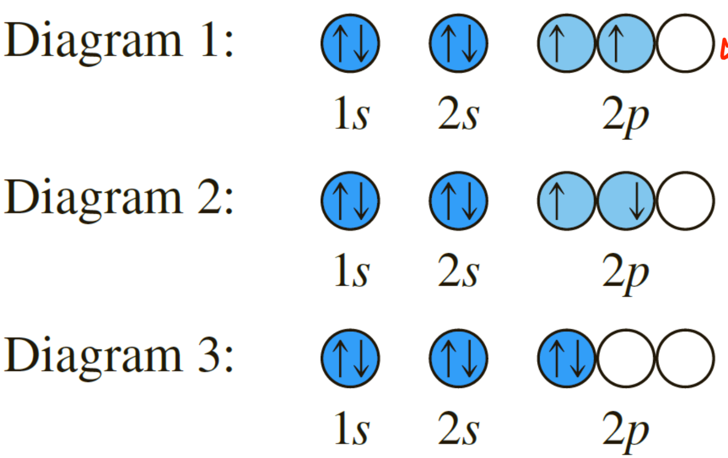
مثل

(Transition metal)

$Fe^{+2} : [Ar]\ 3d^6$

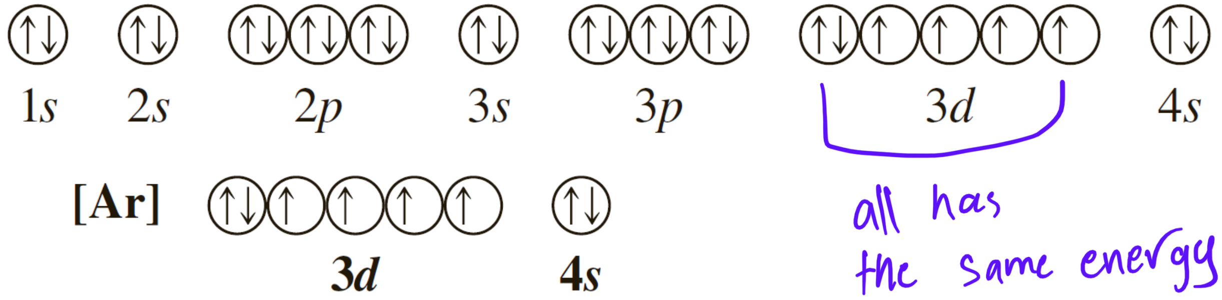
$Fe^{+3} : [Ar]\ 3d^5$

8.4 Orbital Diagrams of Atoms; Hund's Rule



Hund's rule states that *the lowest energy arrangement of electrons in a subshell is obtained by putting electrons into separate orbitals of the subshell with the same spin before pairing electrons*

(Q)Write an orbital diagram for the ground state of the iron atom.



→ net $m_s = \frac{1}{2} + \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$

لـ معناته إله محصلة مغناطيسية

all has the same energy

orbit : n

orbital : m_ℓ

✓ Magnetic Properties of Atoms

paramagnetic substance

↓

At least one unpaired electron

diamagnetic substance

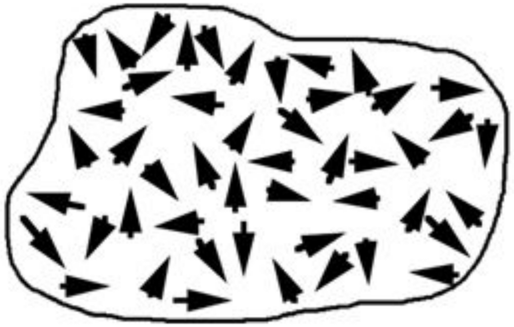
↳ ex: nobel gas

↓

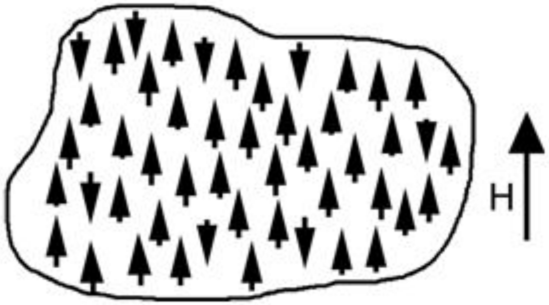
All electrons are paired

Magnetism

Paramagnetism

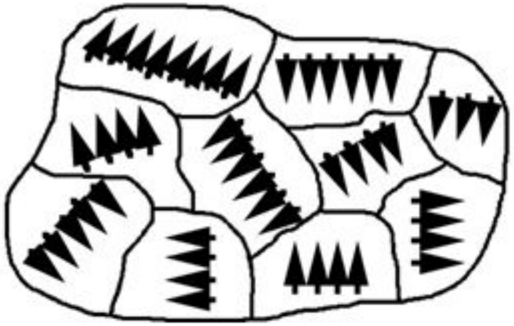


Spins are randomized by thermal energy.

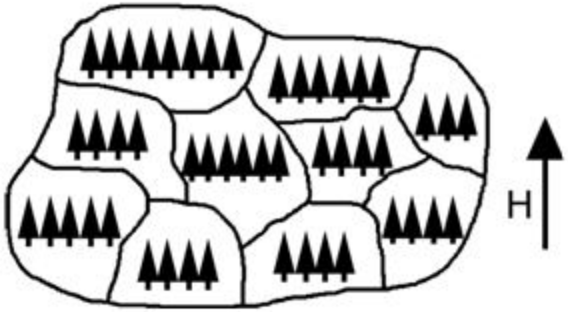


Spins are aligned with or against an applied magnetic field.

Ferromagnetism



Spins are ordered in magnetic domains.

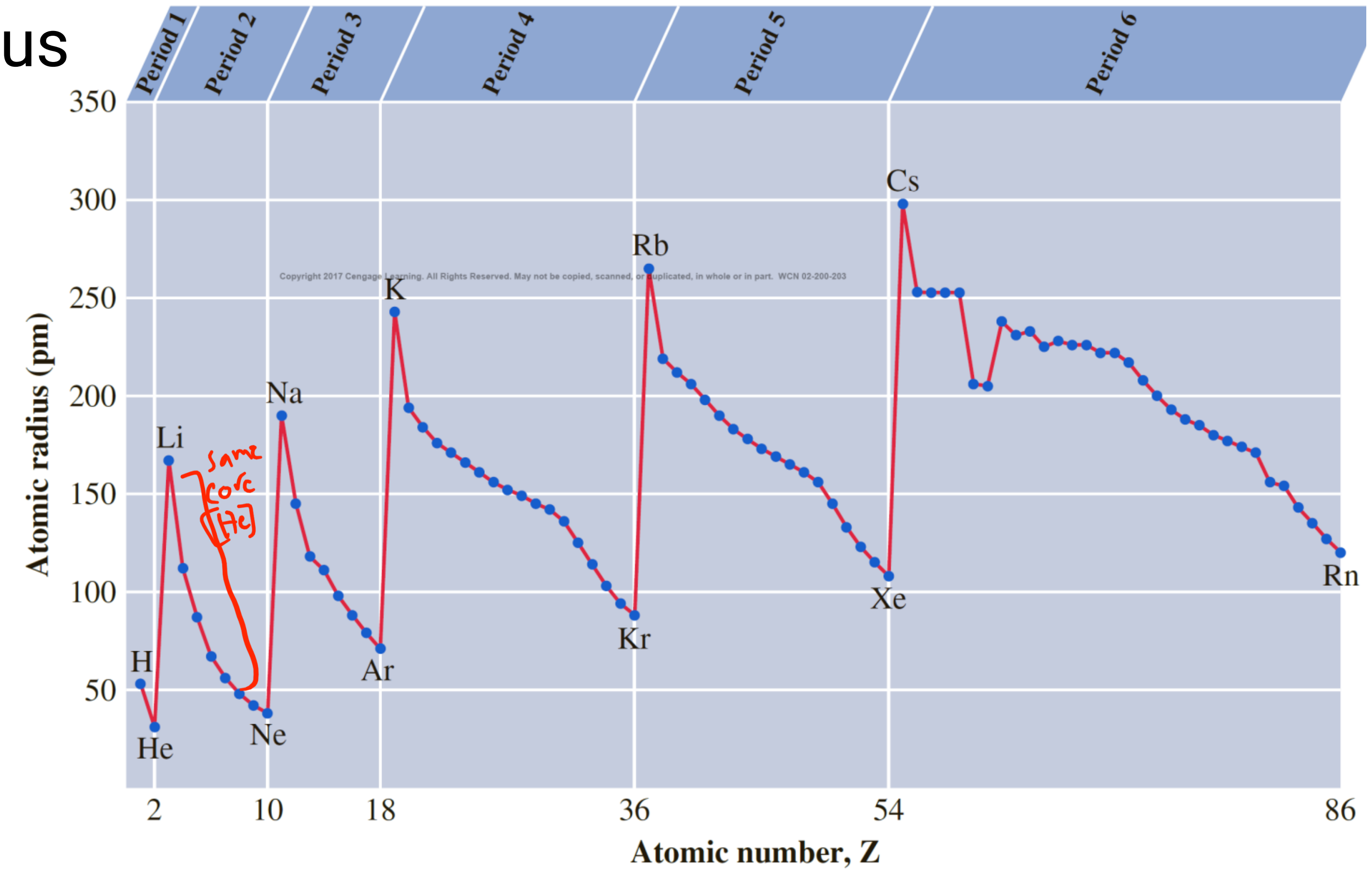


Spins are aligned with an applied magnetic field.

➢ Atomic Radius

(size)

ال Core electrons هما الي بمنعوا جذب النواة



1. Within each period (horizontal row), the atomic radius tends to decrease with increasing atomic number (nuclear charge). effected شحنة النواة الفعالة بتزيد البروتونات بالنواة فتزيد جذبها لإلكترونات المدار الأخير فيقل الحجم

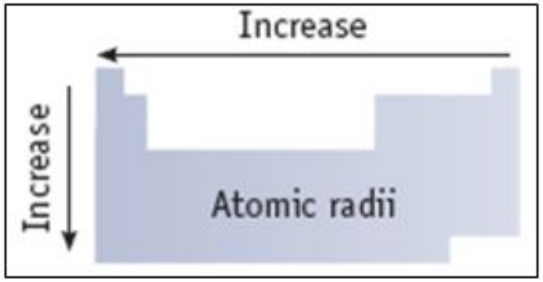
2.Within each group (vertical column), the atomic radius tends to increase with the period number. لأنه بزيد ال shell (n) ← فبزيد الحجم

(Q) Arrange the following in order of increasing atomic radius:

(1) Al, C, Si. C < Si < Al

(2) Na, Be, Mg Be < Mg < Na

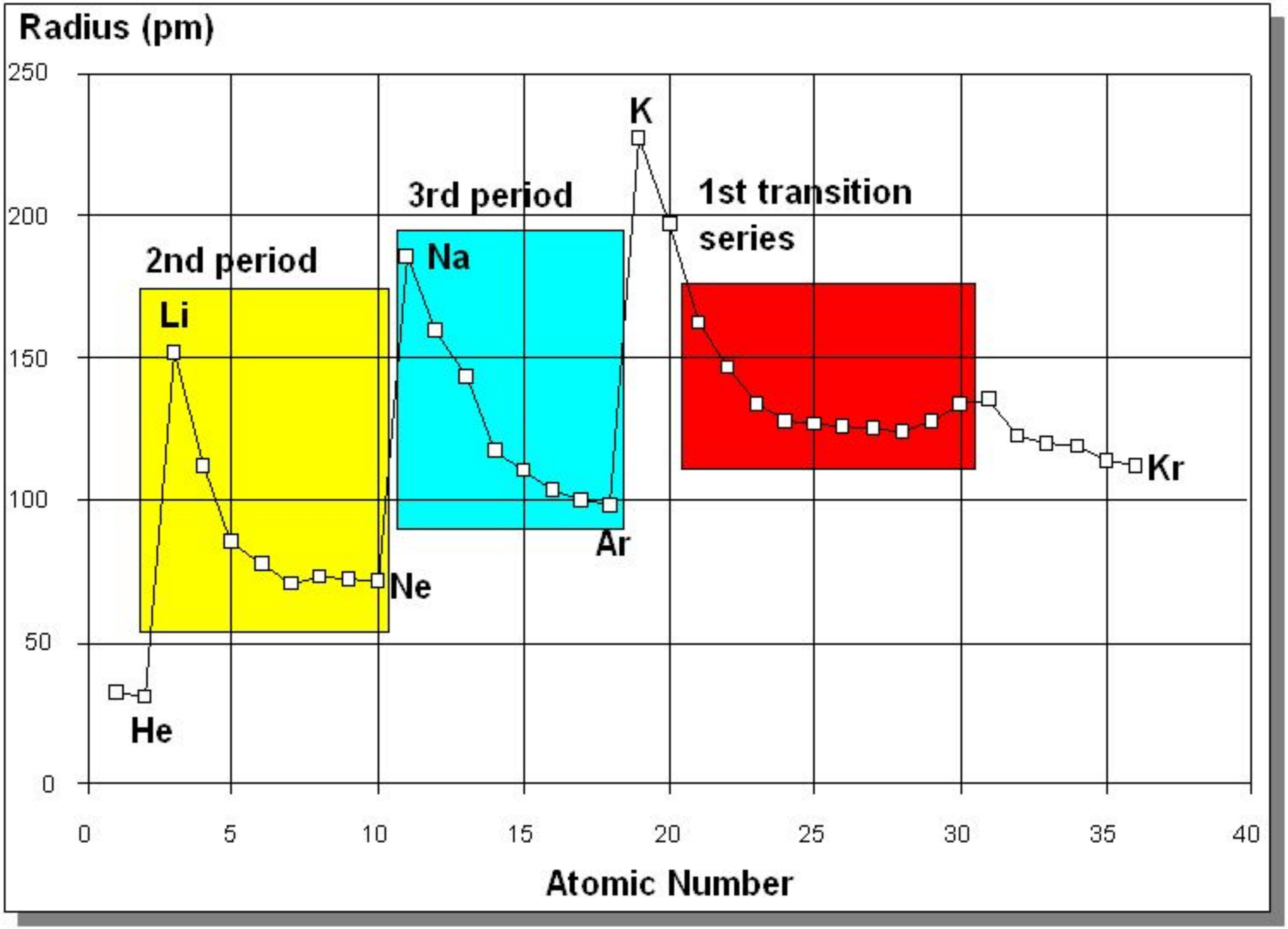
Atomic Size



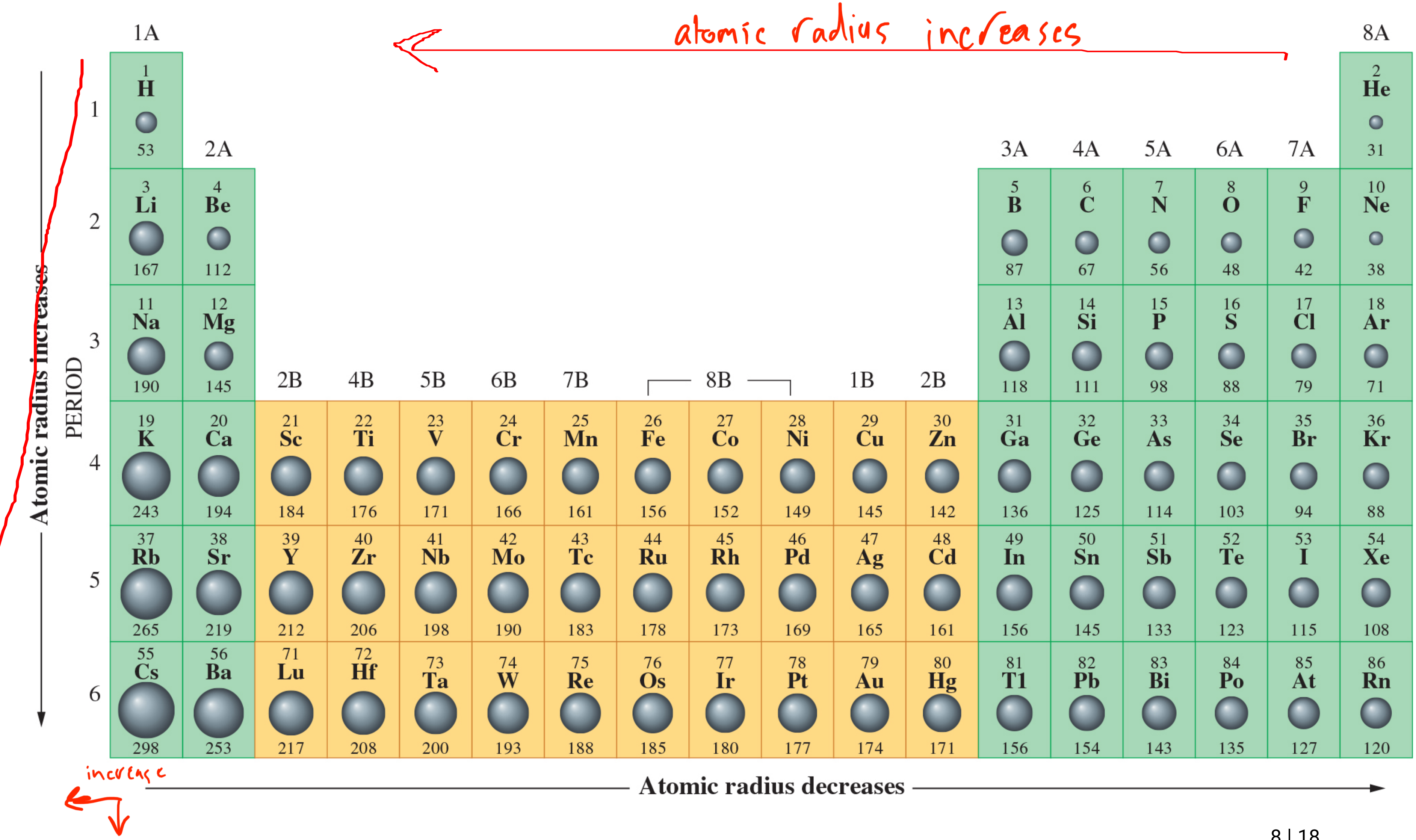
- Size goes UP on going down a group.
- Because electrons are added further from the nucleus, there is less attraction.
- Size goes DOWN on going across a period.

The three properties are studied in the gaseous state

Trends in Atomic Size



A representation of atomic radii is shown below.



PERIOD	1A	2A	2B	4B	5B	6B	7B	8B			1B	2B	3A	4A	5A	6A	7A	8A
1	1 **H** 53																	2 **He** 31
2	3 **Li** 167	4 **Be** 112											5 **B** 87	6 **C** 67	7 **N** 56	8 **O** 48	9 **F** 42	10 **Ne** 38
3	11 **Na** 190	12 **Mg** 145											13 **Al** 118	14 **Si** 111	15 **P** 98	16 **S** 88	17 **Cl** 79	18 **Ar** 71
4	19 **K** 243	20 **Ca** 194	21 **Sc** 184	22 **Ti** 176	23 **V** 171	24 **Cr** 166	25 **Mn** 161	26 **Fe** 156	27 **Co** 152	28 **Ni** 149	29 **Cu** 145	30 **Zn** 142	31 **Ga** 136	32 **Ge** 125	33 **As** 114	34 **Se** 103	35 **Br** 94	36 **Kr** 88
5	37 **Rb** 265	38 **Sr** 219	39 **Y** 212	40 **Zr** 206	41 **Nb** 198	42 **Mo** 190	43 **Tc** 183	44 **Ru** 178	45 **Rh** 173	46 **Pd** 169	47 **Ag** 165	48 **Cd** 161	49 **In** 156	50 **Sn** 145	51 **Sb** 133	52 **Te** 123	53 **I** 115	54 **Xe** 108
6	55 **Cs** 298	56 **Ba** 253	71 **Lu** 217	72 **Hf** 208	73 **Ta** 200	74 **W** 193	75 **Re** 188	76 **Os** 185	77 **Ir** 180	78 **Pt** 177	79 **Au** 174	80 **Hg** 171	81 **Tl** 156	82 **Pb** 154	83 **Bi** 143	84 **Po** 135	85 **At** 127	86 **Rn** 120

Main-Group Elements
s subshell fills

Transition Metals
d subshell fills

Main-Group Elements
p subshell fills

1 **H** $1s^1$	
Atomic number	
Symbol	
Valence-shell configuration	

Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 **H** $1s^1$																	2 **He** $1s^2$
2	3 **Li** $2s^1$	4 **Be** $2s^2$											5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
3	11 **Na** $3s^1$	12 **Mg** $3s^2$											13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$
4	19 **K** $4s^1$	20 **Ca** $4s^2$	21 **Sc** $3d^14s^2$	22 **Ti** $3d^24s^2$	23 **V** $3d^34s^2$	24 **Cr** $3d^54s^1$	25 **Mn** $3d^54s^2$	26 **Fe** $3d^64s^2$	27 **Co** $3d^74s^2$	28 **Ni** $3d^84s^2$	29 **Cu** $3d^{10}4s^1$	30 **Zn** $3d^{10}4s^2$	31 **Ga** $4s^24p^1$	32 **Ge** $4s^24p^2$	33 **As** $4s^24p^3$	34 **Se** $4s^24p^4$	35 **Br** $4s^24p^5$	36 **Kr** $4s^24p^6$
5	37 **Rb** $5s^1$	38 **Sr** $5s^2$	39 **Y** $4d^15s^2$	40 **Zr** $4d^25s^2$	41 **Nb** $4d^45s^1$	42 **Mo** $4d^55s^1$	43 **Tc** $4d^55s^2$	44 **Ru** $4d^75s^1$	45 **Rh** $4d^85s^1$	46 **Pd** $4d^{10}$	47 **Ag** $4d^{10}5s^1$	48 **Cd** $4d^{10}5s^2$	49 **In** $5s^25p^1$	50 **Sn** $5s^25p^2$	51 **Sb** $5s^25p^3$	52 **Te** $5s^25p^4$	53 **I** $5s^25p^5$	54 **Xe** $5s^25p^6$
6	55 **Cs** $6s^1$	56 **Ba** $6s^2$	57-71 Lanthanides	72 **Hf** $5d^26s^2$	73 **Ta** $5d^36s^2$	74 **W** $5d^46s^2$	75 **Re** $5d^56s^2$	76 **Os** $5d^66s^2$	77 **Ir** $5d^76s^2$	78 **Pt** $5d^96s^1$	79 **Au** $5d^{10}6s^1$	80 **Hg** $5d^{10}6s^2$	81 **Tl** $6s^26p^1$	82 **Pb** $6s^26p^2$	83 **Bi** $6s^26p^3$	84 **Po** $6s^26p^4$	85 **At** $6s^26p^5$	86 **Rn** $6s^26p^6$
7	87 **Fr** $7s^1$	88 **Ra** $7s^2$	89-103 Actinides	104 **Rf** $6d^27s^2$	105 **Db** $6d^37s^2$	106 **Sg** $6d^47s^2$	107 **Bh** $6d^57s^2$	108 **Hs** $6d^67s^2$	109 **Mt** $6d^77s^2$	110 **Uun** $6d^87s^2$	111 **Rg** $6d^97s^2$	112 **Cn** $6d^{10}7s^2$	113 **Uut** $7s^27p^1$	114 **Uuq** $7s^27p^2$	115 **Uup** $7s^27p^3$	116 **Uuh** $7s^27p^4$	117 **Uus** $7s^27p^5$	118 **Uuo** $7s^27p^6$

Inner Transition Metals
f subshell fills

57 **La** $5d^16s^2$	58 **Ce** $4f^15d^16s^2$	59 **Pr** $4f^36s^2$	60 **Nd** $4f^46s^2$	61 **Pm** $4f^56s^2$	62 **Sm** $4f^66s^2$	63 **Eu** $4f^76s^2$	64 **Gd** $4f^75d^16s^2$	65 **Tb** $4f^96s^2$	66 **Dy** $4f^{10}6s^2$	67 **Ho** $4f^{11}6s^2$	68 **Er** $4f^{12}6s^2$	69 **Tm** $4f^{13}6s^2$	70 **Yb** $4f^{14}6s^2$	71 **Lu** $4f^{14}5d^16s^2$
89 **Ac** $6d^17s^2$	90 **Th** $6d^27s^2$	91 **Pa** $5f^26d^17s^2$	92 **U** $5f^36d^17s^2$	93 **Np** $5f^46d^17s^2$	94 **Pu** $5f^67s^2$	95 **Am** $5f^77s^2$	96 **Cm** $5f^76d^17s^2$	97 **Bk** $5f^97s^2$	98 **Cf** $5f^{10}7s^2$	99 **Es** $5f^{11}7s^2$	100 **Fm** $5f^{12}7s^2$	101 **Md** $5f^{13}7s^2$	102 **No** $5f^{14}7s^2$	103 **Lr** $5f^{14}7s^27p^1$

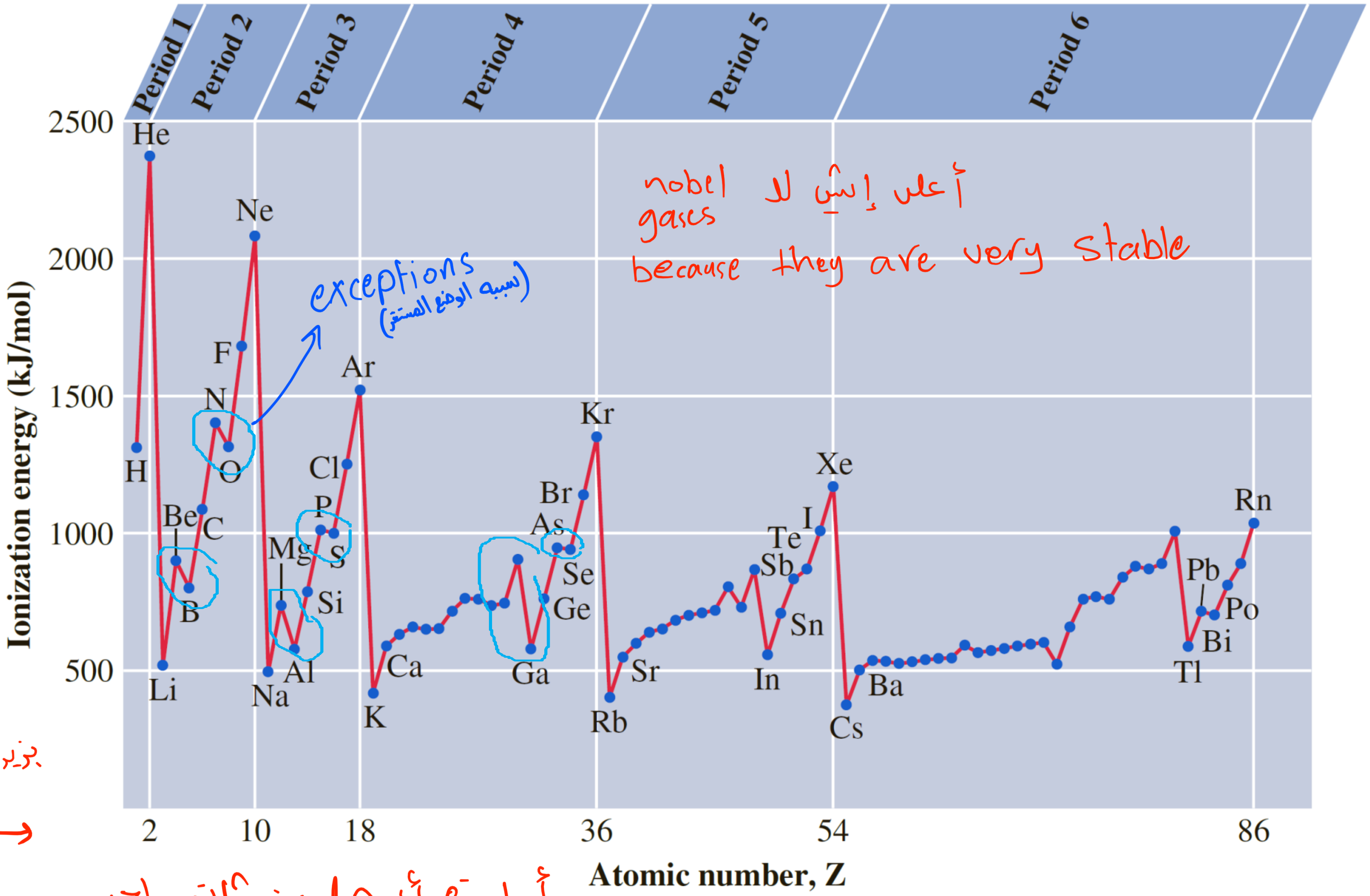
🟨 Main-group elements 🟩 Transition metals 🟦 Inner transition metals

➢ Ionization Energy

$Li \rightarrow Li^+ + e^-$ First ionization energy = 520 kJ/mol

= 5.39 eV (1eV = 96.5 kJ/mol)

منعطي طاقة لننزع إلكترون



exceptions (بسبب الوضع المستقر)

nobel gases أعلى إشي لا because they are very stable

أول e^- أسهلها من ذات واحد

first ionization energy < second IE يعني

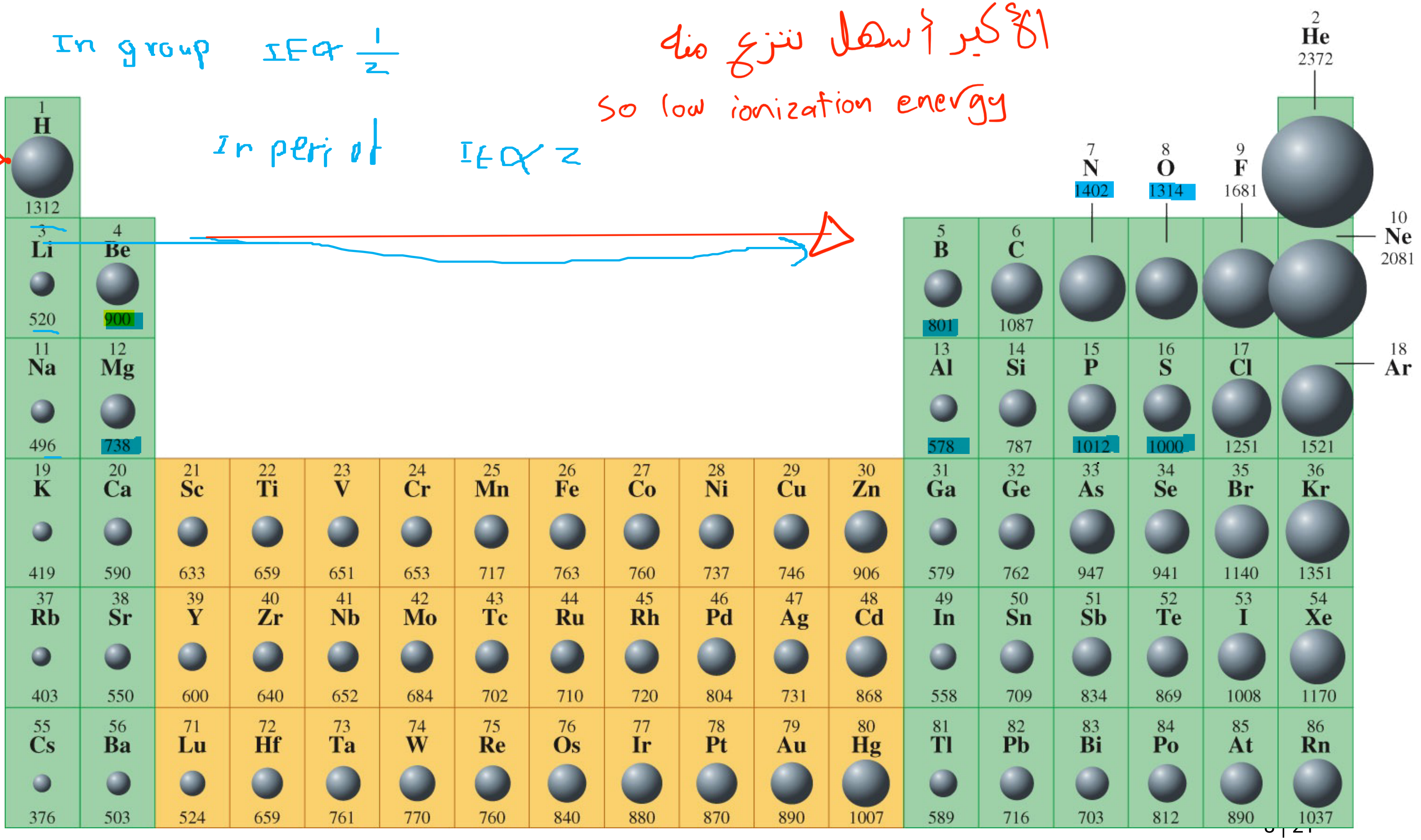
The size of each sphere indicates the size of the ionization energy in the figure below.

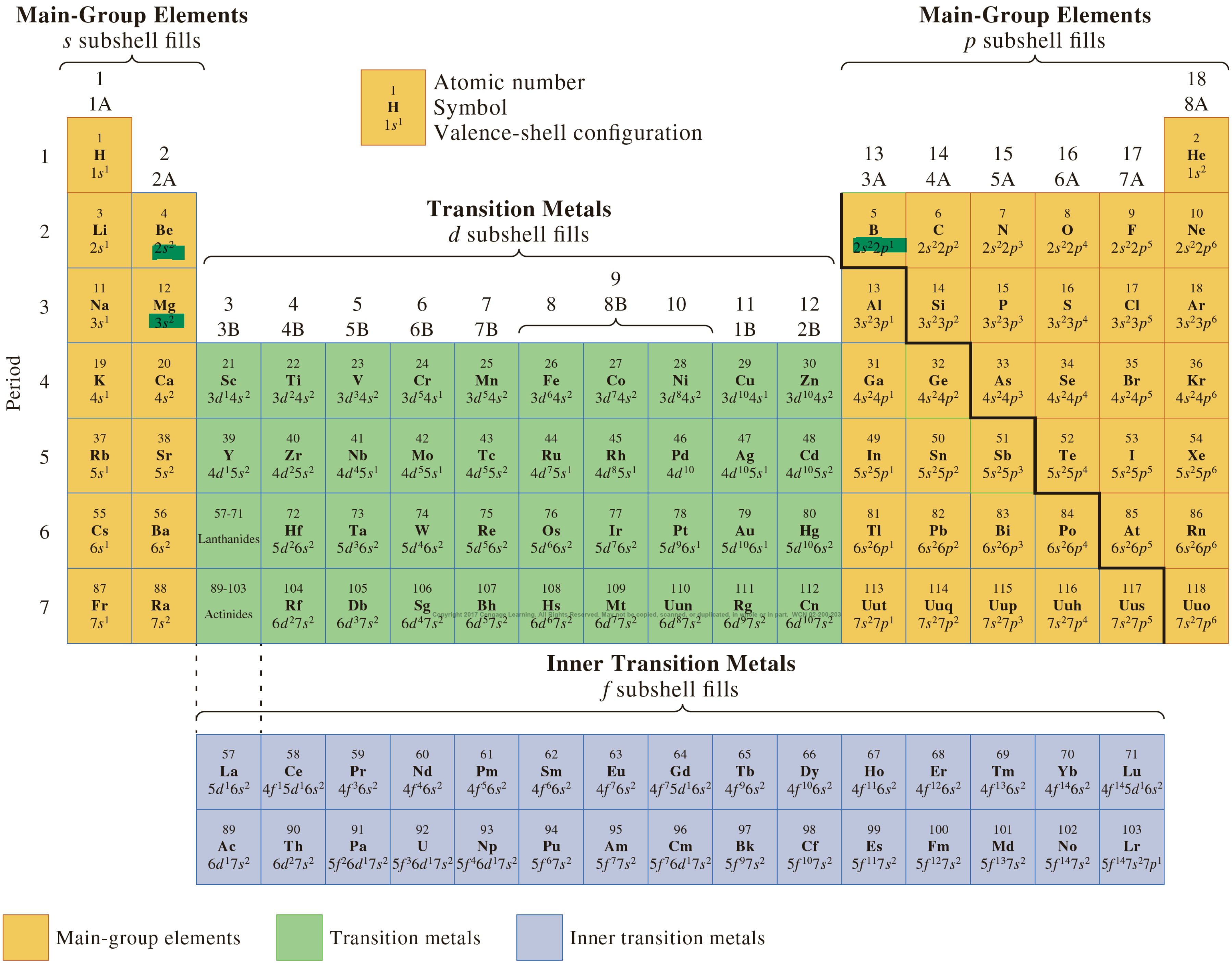
In group $IE \propto \frac{1}{z}$

In period $IE \propto z$

الأكبر أسهل ننزع منه

So low ionization energy





Main-Group Elements
s subshell fills

Main-Group Elements
p subshell fills

1
H
$1s^1$
Atomic number
Symbol
Valence-shell configuration

Transition Metals
d subshell fills

Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 **H** $1s^1$																	2 **He** $1s^2$
2	3 **Li** $2s^1$	4 **Be** $2s^2$											5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
3	11 **Na** $3s^1$	12 **Mg** $3s^2$											13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$
4	19 **K** $4s^1$	20 **Ca** $4s^2$	21 **Sc** $3d^14s^2$	22 **Ti** $3d^24s^2$	23 **V** $3d^34s^2$	24 **Cr** $3d^54s^1$	25 **Mn** $3d^54s^2$	26 **Fe** $3d^64s^2$	27 **Co** $3d^74s^2$	28 **Ni** $3d^84s^2$	29 **Cu** $3d^{10}4s^1$	30 **Zn** $3d^{10}4s^2$	31 **Ga** $4s^24p^1$	32 **Ge** $4s^24p^2$	33 **As** $4s^24p^3$	34 **Se** $4s^24p^4$	35 **Br** $4s^24p^5$	36 **Kr** $4s^24p^6$
5	37 **Rb** $5s^1$	38 **Sr** $5s^2$	39 **Y** $4d^15s^2$	40 **Zr** $4d^25s^2$	41 **Nb** $4d^45s^1$	42 **Mo** $4d^55s^1$	43 **Tc** $4d^55s^2$	44 **Ru** $4d^75s^1$	45 **Rh** $4d^85s^1$	46 **Pd** $4d^{10}$	47 **Ag** $4d^{10}5s^1$	48 **Cd** $4d^{10}5s^2$	49 **In** $5s^25p^1$	50 **Sn** $5s^25p^2$	51 **Sb** $5s^25p^3$	52 **Te** $5s^25p^4$	53 **I** $5s^25p^5$	54 **Xe** $5s^25p^6$
6	55 **Cs** $6s^1$	56 **Ba** $6s^2$	57-71 Lanthanides	72 **Hf** $5d^26s^2$	73 **Ta** $5d^36s^2$	74 **W** $5d^46s^2$	75 **Re** $5d^56s^2$	76 **Os** $5d^66s^2$	77 **Ir** $5d^76s^2$	78 **Pt** $5d^96s^1$	79 **Au** $5d^{10}6s^1$	80 **Hg** $5d^{10}6s^2$	81 **Tl** $6s^26p^1$	82 **Pb** $6s^26p^2$	83 **Bi** $6s^26p^3$	84 **Po** $6s^26p^4$	85 **At** $6s^26p^5$	86 **Rn** $6s^26p^6$
7	87 **Fr** $7s^1$	88 **Ra** $7s^2$	89-103 Actinides	104 **Rf** $6d^27s^2$	105 **Db** $6d^37s^2$	106 **Sg** $6d^47s^2$	107 **Bh** $6d^57s^2$	108 **Hs** $6d^67s^2$	109 **Mt** $6d^77s^2$	110 **Uun** $6d^87s^2$	111 **Rg** $6d^97s^2$	112 **Cn** $6d^{10}7s^2$	113 **Uut** $7s^27p^1$	114 **Uuq** $7s^27p^2$	115 **Uup** $7s^27p^3$	116 **Uuh** $7s^27p^4$	117 **Uus** $7s^27p^5$	118 **Uuo** $7s^27p^6$

Inner Transition Metals
f subshell fills

57 **La** $5d^16s^2$	58 **Ce** $4f^15d^16s^2$	59 **Pr** $4f^36s^2$	60 **Nd** $4f^46s^2$	61 **Pm** $4f^56s^2$	62 **Sm** $4f^66s^2$	63 **Eu** $4f^76s^2$	64 **Gd** $4f^75d^16s^2$	65 **Tb** $4f^96s^2$	66 **Dy** $4f^{10}6s^2$	67 **Ho** $4f^{11}6s^2$	68 **Er** $4f^{12}6s^2$	69 **Tm** $4f^{13}6s^2$	70 **Yb** $4f^{14}6s^2$	71 **Lu** $4f^{14}5d^16s^2$
89 **Ac** $6d^17s^2$	90 **Th** $6d^27s^2$	91 **Pa** $5f^26d^17s^2$	92 **U** $5f^36d^17s^2$	93 **Np** $5f^46d^17s^2$	94 **Pu** $5f^67s^2$	95 **Am** $5f^77s^2$	96 **Cm** $5f^76d^17s^2$	97 **Bk** $5f^97s^2$	98 **Cf** $5f^{10}7s^2$	99 **Es** $5f^{11}7s^2$	100 **Fm** $5f^{12}7s^2$	101 **Md** $5f^{13}7s^2$	102 **No** $5f^{14}7s^2$	103 **Lr** $5f^{14}7s^27p^1$

🟨 Main-group elements
🟩 Transition metals
🟦 Inner transition metals

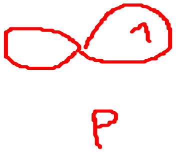
II ionization energy III

Be $1s^2 2s^2$ > B[He] $2s^2$ $2p^1$

filled not filled

Mg [Ne]$3s^2$ > Al [Ne]$3s^2$ $3p^1$

filled not filled



V

N

[He]$3s^2 3p^3$

↿ ↿ ↿

p^3

VI

O

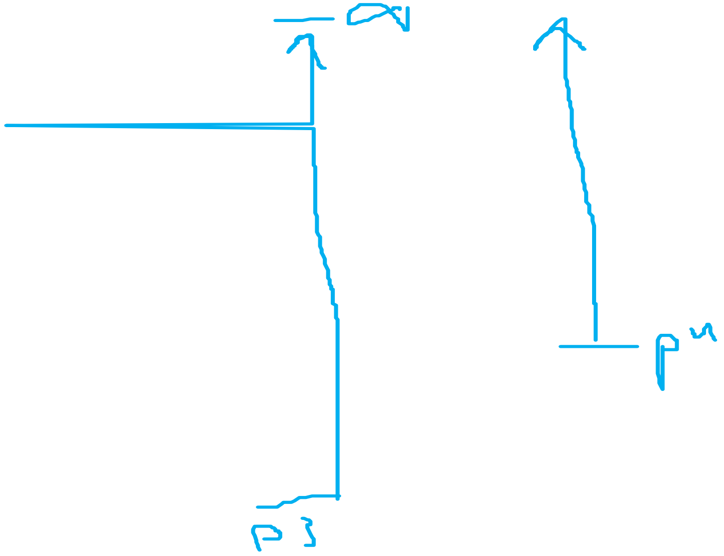
[He] $3s^2$ $3p^4$

⇅ ↿ ↿

p^4

Half-filled

more stable



- high values of *first ionization energy* associated with the noble gases
- very low values of *first ionization energy* associated with the group 1 elements;
- general increase in values of *first ionization energy* as a given period is crossed →
- Ionization energies tend to decrease going down any column. This is because atomic size increases going down the column.

so it's easier to Lose electron

Exceptions:

(Less stable not filled)

- (B<Be) 3A element (B)(ns^2np^1) has smaller ionization energy than the preceding 2A element (Be)(ns^2). Or (Al < Mg)

تنافر فأسهل نزع الـe ← ↑↓ ↑ ↑

- (O<N)6A element (O)(ns^2np^4) has smaller ionization energy than the preceding 5A element (N) (ns^2np^3) . Or (S < P)

As a result of electron repulsion

نص
ممتلئ
يعني أكثر استقرار
فبده طاقة أعلى
↑ ↑ ↑

لما نوصل ال core
يصير صعب كثير الفقد
للالكترون

Table 8.3 Successive Ionization Energies of the First Ten Elements (kJ/mol)*

Element	First	Second	Third	Fourth	Fifth	Sixth	Seventh
H	1312						
He	2372	5250					
Li	520	7298	11,815				
Be	900	1757	14,848	21,006			
B	801	2427	3660	25,026	32,827		
C	1086	2353	4620	6223	37,831	47,277	
N	1402	2856	4578	7475	9445	53,267	64,360
O	1314	3388	5300	7469	10,990	13,326	71,330
F	1681	3374	6050	8408	11,023	15,164	17,868
Ne	2081	3952	6122	9371	12,177	15,238	19,999

لما نقيم الإلكترون الـ valence s بصير مستقر بعد الاستقرار بتنط الزيادة

$1s^2 2s^1$

$1s^1$

$1s^2 2s^2$

$1s^2 2s^1$

$1s^2 2s^2 2p^1$

معناة B → من المجموعة الثالثة

Exercise 8.7 The first ionization energy of the chlorine atom is 1251 kJ/mol. which of the following values would be the more likely ionization energy for the iodine atom. Explain.

a. 1000 kJ/mol. b. 1400 kJ/mol.

قيمة ال I

تحت ال Cl

$\underset{13}{Al}\ [Ne]\ 3s^2\ 3p^1 \rightarrow$ 3A مجموعة

القفزة بالرابعة

$[Ne]3s^2 3p^1$ $Al \longrightarrow Al^{+1} + e^1$ I_1

$[Ne]3s^2$ $Al^{+} \longrightarrow Al^{+2} + e^-$ I_2

$[Ne]3s^1$ $Al^{+2} \longrightarrow Al^{+3} + e^-$ I_3

$[Ne]$ $Al^{+3} \longrightarrow Al^{+4} + e^-$ I_4

$(1s^2 2s^2 2p^6) \rightarrow$ وصلنا
core لل

Full-filed

Isoelectronic

$I_4 >>> I_3 > I_2 > I_1$

1/400

8.26 Which of the following atoms, designated by their electron configurations, has the *highest* ionization energy?

- a $[Ne]3s^23p^2$
- b $[Ne]3s^23p^3$
- c $[Ar]3d^{10}4s^24p^3$
- d $[Kr]4d^{10}5s^25p^3$
- e $[Xe]4f^{14}5d^{10}6s^26p^3$

n=3

group 5

b > c, d, e

b > a

(b)

8.27 When trying to remove electrons from Be, which of the following sets of ionization energy makes the most sense going from first to third ionization energy? Explain your answer.

- a First IE 900 KJ/mol, second IE 1750 kJ/mol, third IE 15,000 kJ/mol
- b First IE 1750 KJ/mol, second IE 900 kJ/mol, third IE 15,000 kJ/mol مستحيل يقل
- c First IE 15,000 KJ/mol, second IE 1750 kJ/mol, third IE 900 kJ/mol مستحيل تقل
- d First IE 900 KJ/mol, second IE 15,000 kJ/mol, third IE 22,000 kJ/mol هاي مجموعة أولى
- e First IE 900 KJ/mol, second IE 1750 kJ/mol, third IE 1850 kJ/mol No Jump

Be مجموعة
ثانية إذاً ال
Jump بالثالثة

(a)

8.28 Consider the following orderings.

I. Al $<$ Si $<$ P $<$ S

II. Be $<$ Mg $<$ Ca $<$ Sr

III. I $<$ Br $<$ Cl $<$ F

Which of these give(s) a correct trend in atomic size?

a I only
b II only
c III only
d I and II only
e II and III only

(b)

➢ Electron Affinity

Positive

is defined as *the energy required to remove an electron from the atom's negative ion (in its ground state)*

$$Cl([Ne]3s^2 3p^5) + e^- \longrightarrow Cl^-([Ne]3s^2 3p^6);\ \Delta E = -349 \text{ kJ/mol}$$

Experimentally EA is determined by the following eqn.

$$Cl^-([Ne]3s^2 3p^6) \longrightarrow Cl([Ne]3s^2 3p^5) + e^-;\ \Delta E = +349 \text{ kJ/mol}$$

Change in Energy

electron Affinity

4A

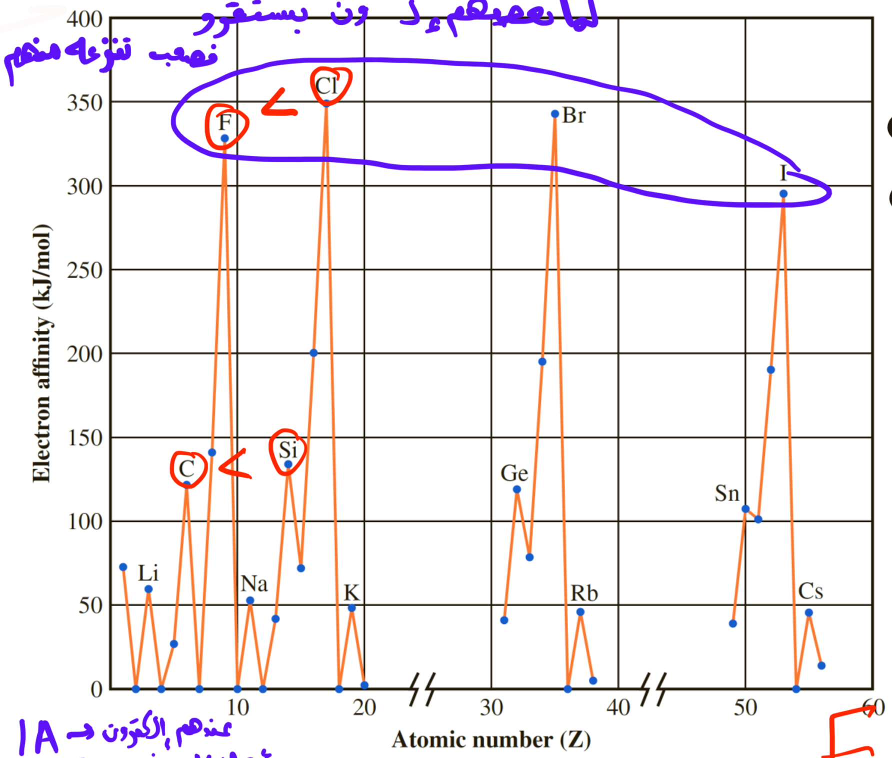
$$Ge([Ar]4s^2 4p^2) + e^- \longrightarrow Ge^-([Ar]4s^2 4p^3);\ \Delta E = -119 \text{ kJ/mol (EA} = 119 \text{ kJ/mol)}$$

5A

$$As([Ar]4s^2 4p^3) + e^- \longrightarrow As^-([Ar]4s^2 4p^4);\ \Delta E = -78 \text{ kJ/mol (EA} = 78 \text{ kJ/mol)}$$

$EA_{Ge} > EA_{As}$ → exception لأنه الـ Ge إذا أخذ e^- بصير أكثر استقرارًا (بصير نصف ممتلئ) → و As إذا أخذ e^- بقل الاستقرار لأنه ببطل نصف ممتلئ

✓ In the Group 5A element (arsenic, As, in the above list), the added electron must pair up with one of the *np* electrons since all of the *np* orbitals have one electron, whereas in the preceding element the extra electron goes into an empty *np* orbital. This pairing of electrons in an orbital requires some energy, resulting in a smaller electron affinity for the Group 5A element compared with the preceding 4A element.



لما نعطيهم إلكترون بستقرو
فصعب تنزعه منهم

1A → عندهم إلكترون
أصلا زايد فسهل يتخلصوا
من إلكترون جديد

$Ga([Ar]4s^{2}4p^{1}) + e^{-} \longrightarrow Ga^{-}([Ar]4s^{2}4p^{2}); \Delta E = -41$ kJ/mol (

$Ge([Ar]4s^{2}4p^{2}) + e^{-} \longrightarrow Ge^{-}([Ar]4s^{2}4p^{3}); \Delta E = -119$ kJ/mol

$As([Ar]4s^{2}4p^{3}) + e^{-} \longrightarrow As^{-}([Ar]4s^{2}4p^{4}); \Delta E = -78$ kJ/mol (

$Se([Ar]4s^{2}4p^{4}) + e^{-} \longrightarrow Se^{-}([Ar]4s^{2}4p^{5}); \Delta E = -195$ kJ/mol

$Br([Ar]4s^{2}4p^{5}) + e^{-} \longrightarrow Br^{-}([Ar]4s^{2}4p^{6}); \Delta E = -325$ kJ/mol

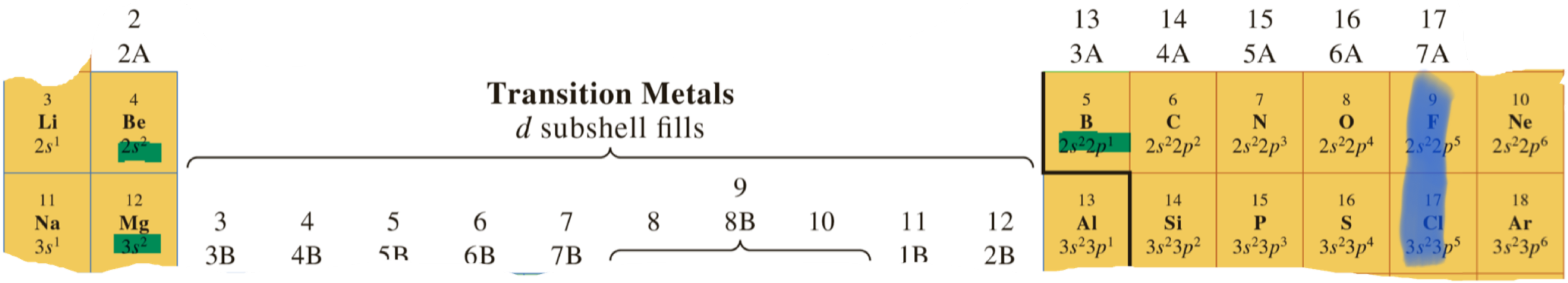
→ nuclear charge increases
so attraction to electron
increases

$EA_{1A} > EA_{2} \quad EA_{(4A)} > EA_{(5A)}$

- ✓ In a given period, the electron affinity rises from the Group 1A element to the Group 7A element but with sharp drops in the Group 2A and Group 5A elements.
- ✓ Group 8A elements (noble gases) have zero or small negative values (indicating unstable negative ions)

لأنه ينفتح orbital جديد
سهل يفقده

- ✓ Group 6A and Group 7A elements have the largest electron affinities of any of the other main-group elements



1	2 2A		13 3A	14 4A	15 5A	16 6A	17 7A	
3 **Li** $2s^1$	4 **Be** $2s^2$		5 **B** $2s^22p^1$	6 **C** $2s^22p^2$	7 **N** $2s^22p^3$	8 **O** $2s^22p^4$	9 **F** $2s^22p^5$	10 **Ne** $2s^22p^6$
11 **Na** $3s^1$	12 **Mg** $3s^2$		13 **Al** $3s^23p^1$	14 **Si** $3s^23p^2$	15 **P** $3s^23p^3$	16 **S** $3s^23p^4$	17 **Cl** $3s^23p^5$	18 **Ar** $3s^23p^6$

Transition Metals
d subshell fills

3	4	5	6	7	8	9	10	11	12
3B	4B	5B	6B	7B		8B		1B	2B

$EA_{n=3} > EA_{n=2}$

أكبر تنافر أقل ← $Cl_{size} > F_{size}$

لما أصغر تنافر أعلى

$Si_{EA} > C_{EA}$

$Cl_{EA} > F_{EA}$

$S_{EA} > O_{EA}$

$P_{EA} > N_{EA}$

Cl

EA أعلى