Understanding the Periodic Table

vrije Universiteit *amsterdam*

PERIODIC TABLE OF THE ELEMENTS

GROUP IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA	IB	IIB	IIIB	IVB	VB	VIB	VIIB	VIII
1 1.0079 H															2 4.00260 He
3 6.941 Li	4 9.01218 Be									5 10.81 B	6 12.011 C	7 14.0067 N	8 15.9994 O	9 18.998403 F	10 20.179 Ne
11 22.98977 Na	12 24.305 Mg									13 26.98154 Al	14 28.0855 Si	15 30.97376 P	16 32.06 S	17 35.453 Cl	18 39.948 Ar
19 39.0983 K	20 40.08 Ca	21 44.9559 Sc	22 47.90 Ti	23 50.9415 V	24 51.996 Cr	25 54.9380 Mn	26 55.847 Fe	27 58.9332 Co	28 58.70 Ni	29 63.546 Cu	30 65.38 Zn	31 69.72 Ga	32 72.59 Ge	33 74.9216 As	34 78.96 Se	35 79.904 Br	36 83.80 Kr
37 85.4678 Rb	38 87.62 Sr	39 88.9059 Y	40 91.22 Zr	41 92.9064 Nb	42 95.94 Mo	43 (98) Tc	44 101.07 Ru	45 102.9055 Rh	46 106.4 Pd	47 107.868 Ag	48 112.41 Cd	49 114.82 In	50 118.69 Sn	51 121.75 Sb	52 127.60 Te	53 126.9045 I	54 131.30 Xe
55 132.9054 Cs	56 137.33 Ba	57 138.9055 La ★	72 178.49 Hf	73 180.9479 Ta	74 183.85 W	75 186.207 Re	76 190.2 Os	77 192.22 Ir	78 195.09 Pt	79 196.9665 Au	80 200.59 Hg	81 204.37 Tl	82 207.2 Pb	83 208.9804 Bi	84 (209) Po	85 (210) At	86 (222) Rn
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★	58 140.12 Ce	59 140.9077 Pr	60 144.24 Nd	61 (145) Pm	62 150.4 Sm	63 151.96 Eu	64 157.25 Gd	65 158.9254 Tb	66 162.50 Dy	67 164.9304 Ho	68 167.26 Er	69 168.9342 Tm	70 173.04 Yb	71 174.967 Lu
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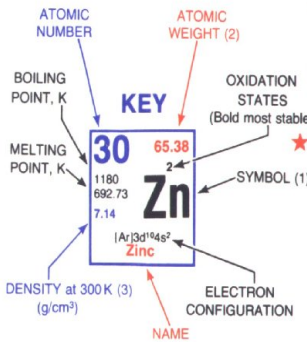
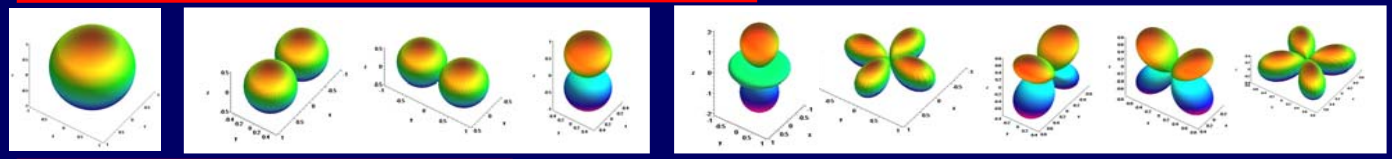


n=5

n=4

n=3



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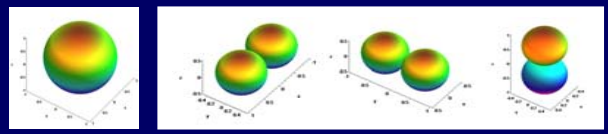
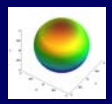


$$n = 1,2,3.....$$

$$l \leq n-1$$

$$m = l, l-1, l-2, ... -l$$



n=1

Energy levels (n,l,m) in the hydrogen atom

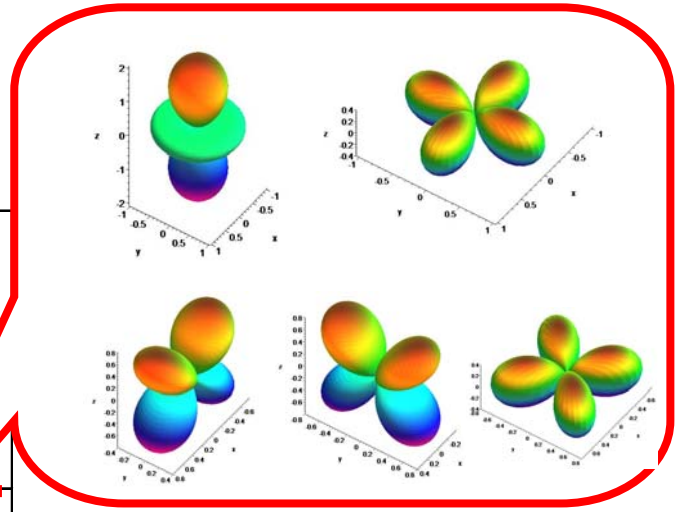
n	ε_n (eV)	l=0	l=1	l=2	l=3	l=….	degeneracy
n							n^2
..	…..						…..
4	ε_4= -0.85	4s	4p	4d	4f		1+3+5+7 = 16
3	ε_3= -1.51	3s	3p	3d			1+3+5 = 9
2	ε_2= -3.40	2s	2p				1+3 = 4
1	ε_1= -13.6	1s					1

$$n = 1,2,3.....$$

$$l \le n-1$$

$$m = l, l-1, l-2, ... -l$$

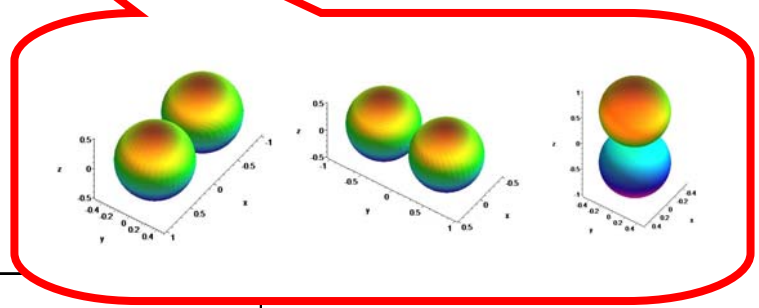
n	ε_n (eV)	l=0	l=1	l=2
n				
..	…..			
4	ε_4= -0.85	4s	4p	4d
3	ε_3= -1.51	3s	3p	3d
2	ε_2= -3.40	2s	2p	
1	ε_1= -13.6	1s		

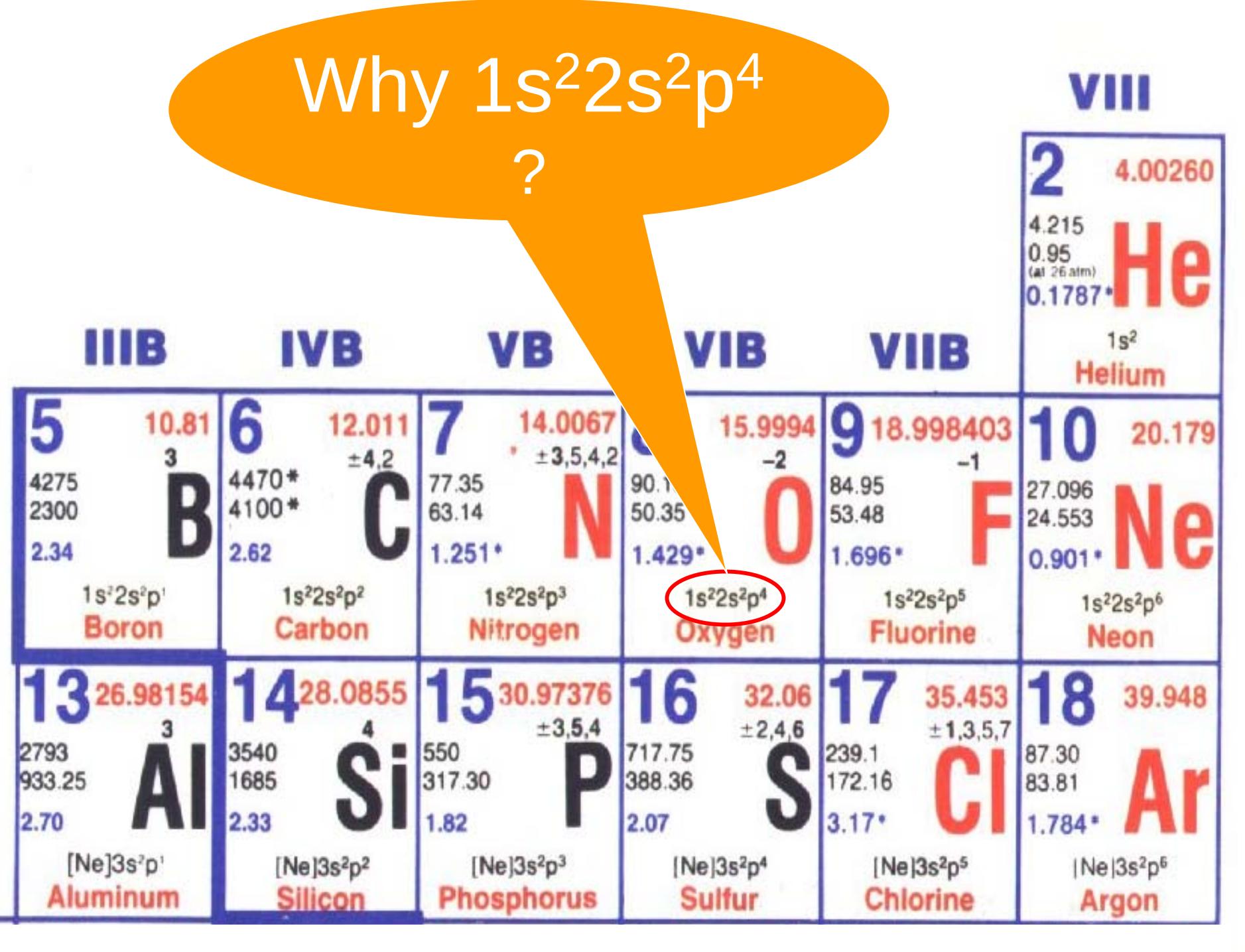


$$n = 1,2,3.....$$

$$l \le n-1$$

$$m = l, l-1, l-2, ... -l$$




Why $1s^2 2s^2 p^4$?
VIII
2 4.00260
4.215
0.95
(at 26 atm)
0.1787*
He
$1s^2$
Helium
IIIB
IVB
VB
VIB
VIIB
5 10.81
3
4275
2300
2.34
B
$1s^2 2s^2 p^1$
Boron
6 12.011
±4,2
4470*
4100*
2.62
C
$1s^2 2s^2 p^2$
Carbon
7 14.0067
±3,5,4,2
77.35
63.14
1.251*
N
$1s^2 2s^2 p^3$
Nitrogen
15.9994
−2
90.1
50.35
1.429*
O
$1s^2 2s^2 p^4$
Oxygen
9 18.998403
−1
84.95
53.48
1.696*
F
$1s^2 2s^2 p^5$
Fluorine
10 20.179
27.096
24.553
0.901*
Ne
$1s^2 2s^2 p^6$
Neon
13 26.98154
3
2793
933.25
2.70
Al
[Ne]$3s^2 p^1$
Aluminum
14 28.0855
4
3540
1685
2.33
Si
[Ne]$3s^2 p^2$
Silicon
15 30.97376
±3,5,4
550
317.30
1.82
P
[Ne]$3s^2 p^3$
Phosphorus
16 32.06
±2,4,6
717.75
388.36
2.07
S
[Ne]$3s^2 p^4$
Sulfur
17 35.453
±1,3,5,7
239.1
172.16
3.17*
Cl
[Ne]$3s^2 p^5$
Chlorine
18 39.948
87.30
83.81
1.784*
Ar
[Ne]$3s^2 p^6$
Argon

No more than 2 electrons per state

Pauli exclusion principle

Energy levels in an H-like atom

$$m\frac{v^2}{r} = \frac{e\,(Ze)}{4\pi\varepsilon_o r^2}$$

$$E = \frac{1}{2}mv^2 - \frac{Ze^2}{4\pi\varepsilon_o r} = -\frac{Ze^2}{8\pi\varepsilon_o r}$$

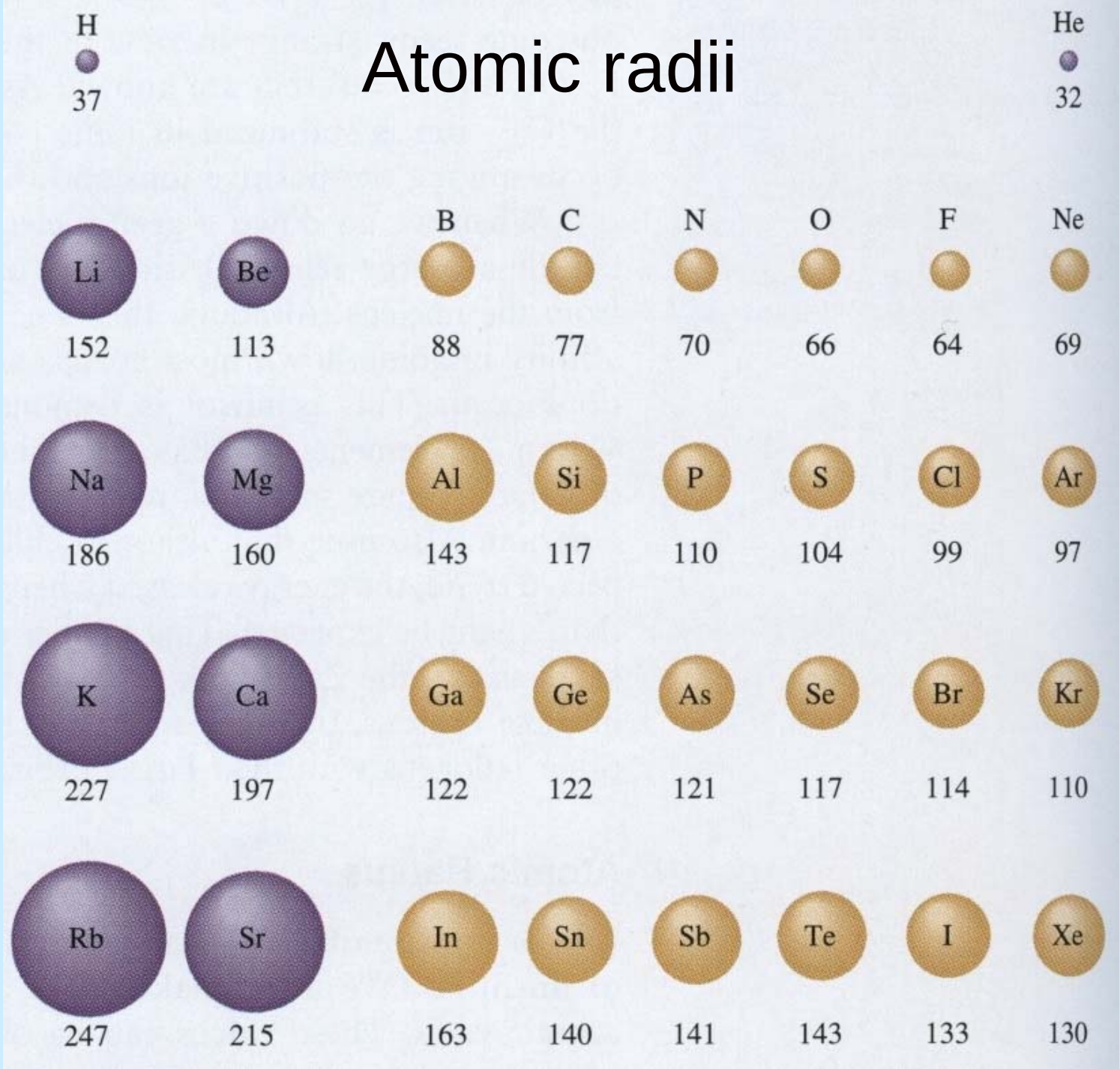
$$E_n = -\frac{mZ^2e^4}{2(4\pi\varepsilon_0)^2\hbar^2}\frac{1}{n^2}$$

$$2\pi r = n\lambda$$

Quantum physics

$$r_n = \frac{4\pi\varepsilon_o\hbar^2}{mZe^2}n^2$$

Atomic radii



GROUP

IA

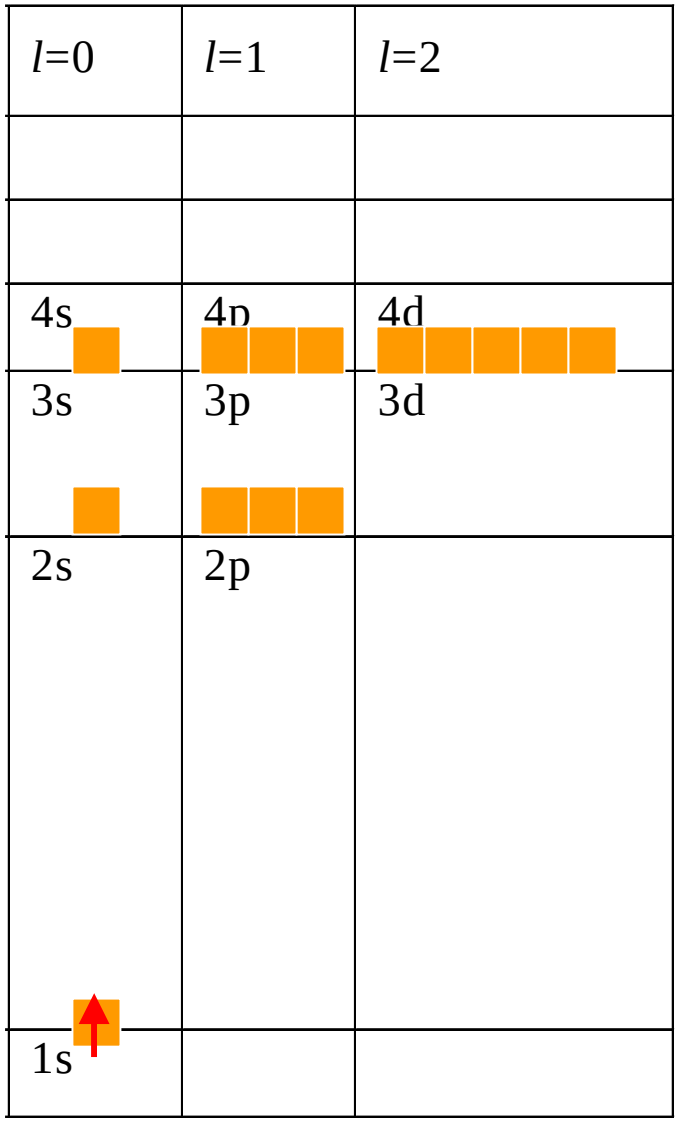
1	1.0079
20.268 14.025 0.0899*	1 H
$1s^1$	
Hydrogen	

IIA

3	6.941	4	9.01218
1615 453.7 0.53	1 Li	2745 1560 1.85	2 Be
$1s^22s^1$		$1s^22s^2$	
Lithium		Beryllium	

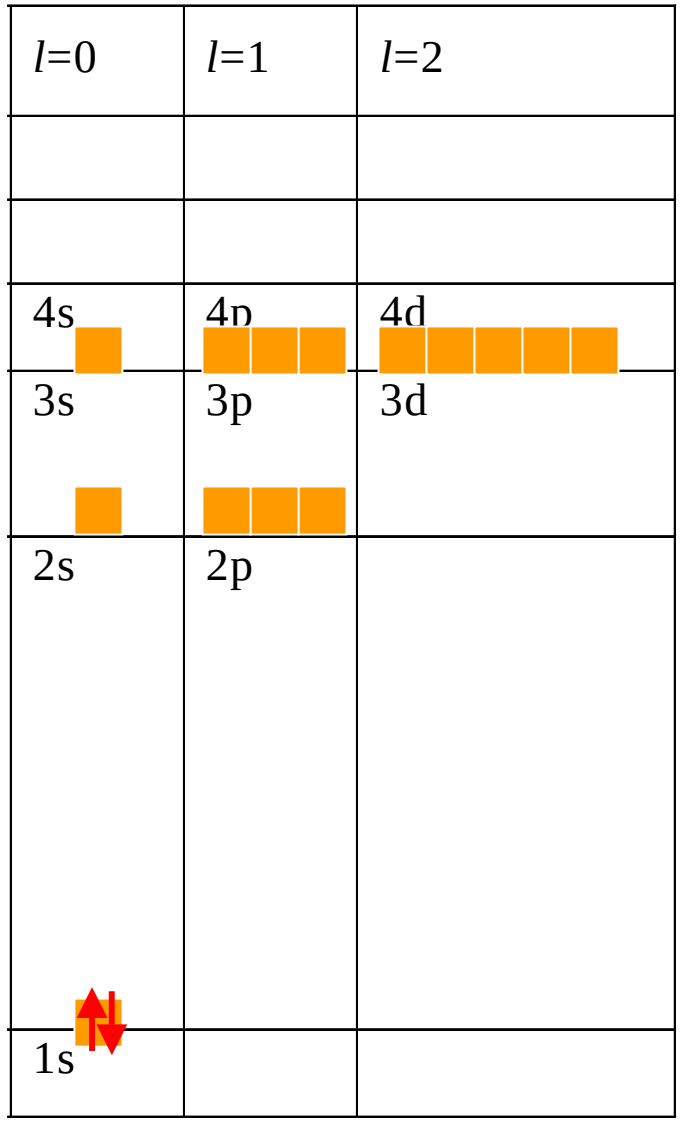
11	22.98977	12	24.305
1156 371.0 0.97	1 Na	1363 922 1.74	2 Mg
$[Ne]3s^1$		$[Ne]3s^2$	
Sodium		Magnesium	

IIIA IVA VA VIA V



H

1s



He

$1s^2$

IIIB	IVB	VB	VIB	VIIB	VIII	
					2 4.00260 4.215 0.95 (at 26 atm) 0.1787* **He** $1s^2$ Helium	
5 10.81 3 4275 2300 2.34 **B** $1s^2 2s^2 p^1$ Boron	6 12.011 ±4,2 4470* 4100* 2.62 **C** $1s^2 2s^2 p^2$ Carbon	7 14.0067 ±3,5,4,2 77.35 63.14 1.251* **N** $1s^2 2s^2 p^3$ Nitrogen	8 15.9994 −2 90.18 50.35 1.429* **O** $1s^2 2s^2 p^4$ Oxygen	9 18.998403 −1 84.95 53.48 1.696* **F** $1s^2 2s^2 p^5$ Fluorine	10 20.179 27.096 24.553 0.901* **Ne** $1s^2 2s^2 p^6$ Neon	
13 26.98154 3 2793 933.25 2.70 **Al** [Ne]$3s^2 p^1$ Aluminum	14 28.0855 4 3540 1685 2.33 **Si** [Ne]$3s^2 p^2$ Silicon	15 30.97376 ±3,5,4 550 317.30 1.82 **P** [Ne]$3s^2 p^3$ Phosphorus	16 32.06 ±2,4,6 717.75 388.36 2.07 **S** [Ne]$3s^2 p^4$ Sulfur	17 35.453 ±1,3,5,7 239.1 172.16 3.17* **Cl** [Ne]$3s^2 p^5$ Chlorine	18 39.948 87.30 83.81 1.784* **Ar** [Ne]$3s^2 p^6$ Argon	

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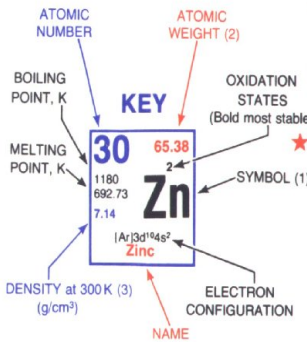
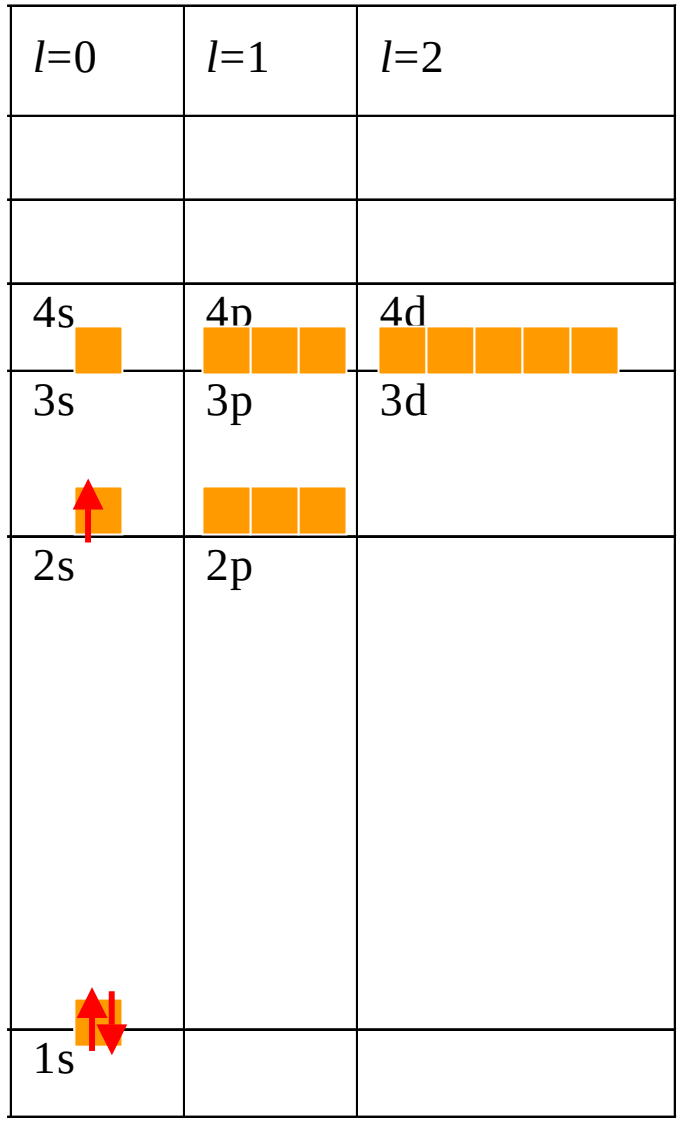
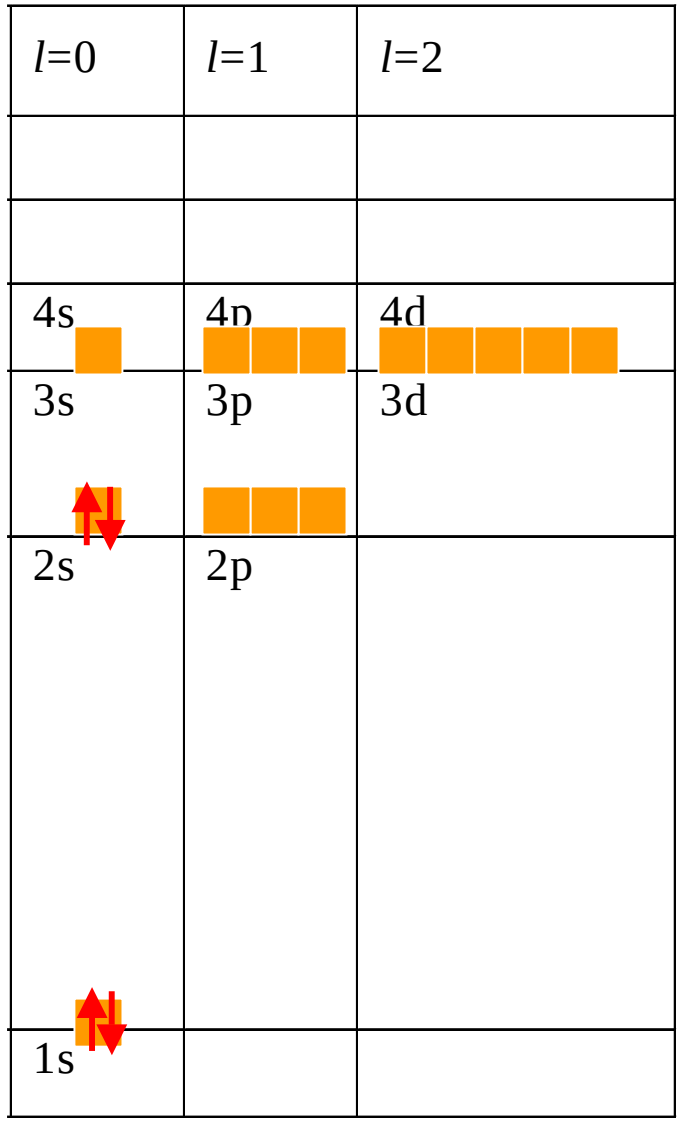




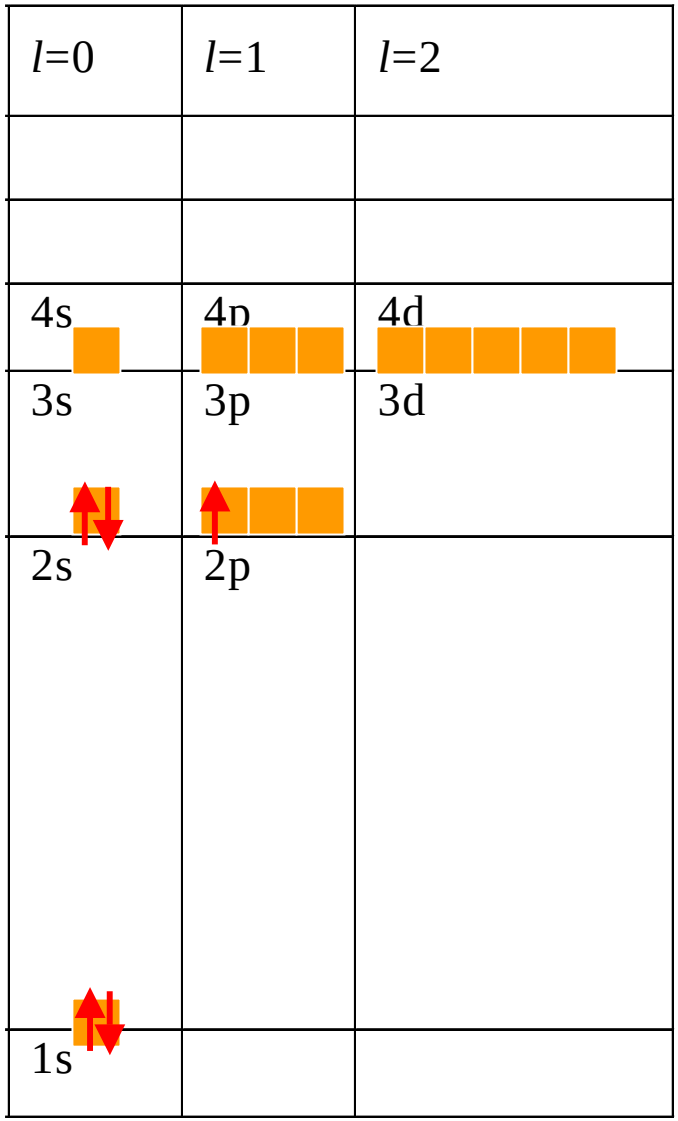
Li

$1s^2 2s^1$



Be

$1s^2 2s^2$



B

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

Is this the best possibility ?

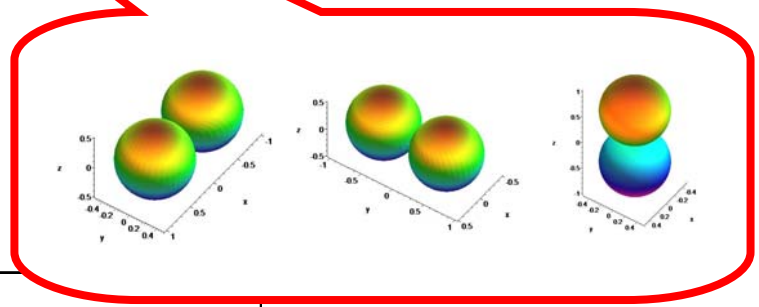
C

4s 4d

3s 3p 3d

2s 2p

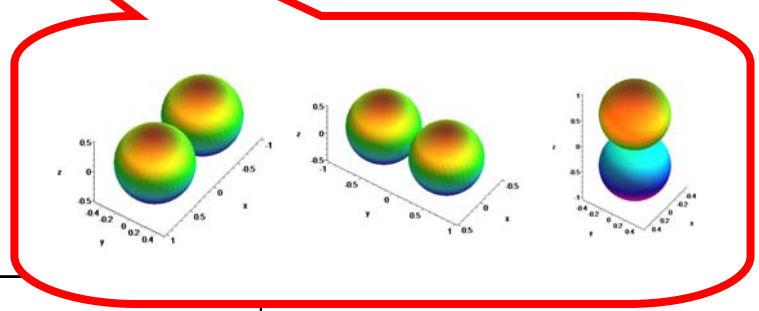
1s

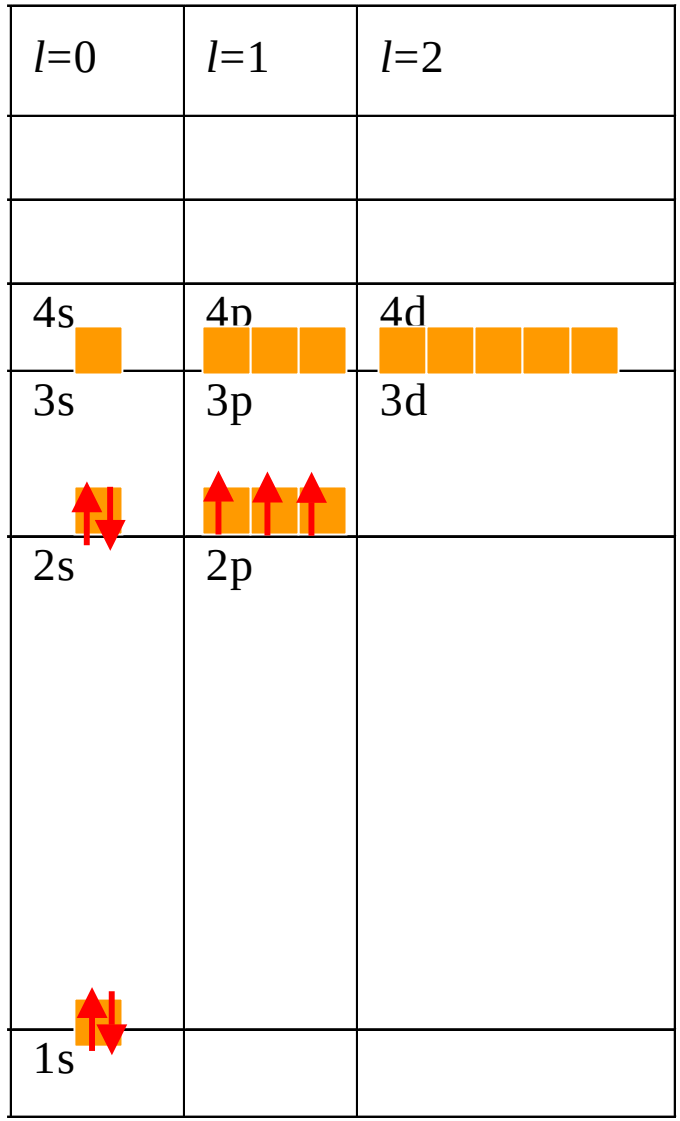


l=0	*l*=1	*l*=2
4s	4p	4d
3s	3p	3d
2s	2p	
1s		

C

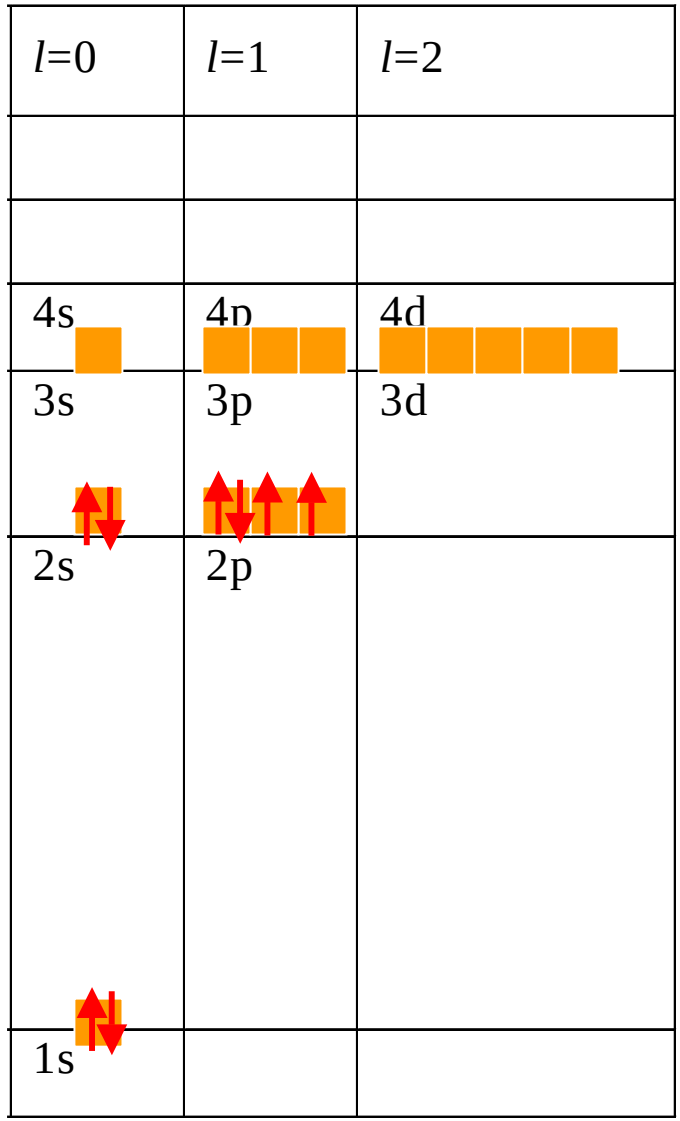
$1s^2 2s^2 2p^2$





N

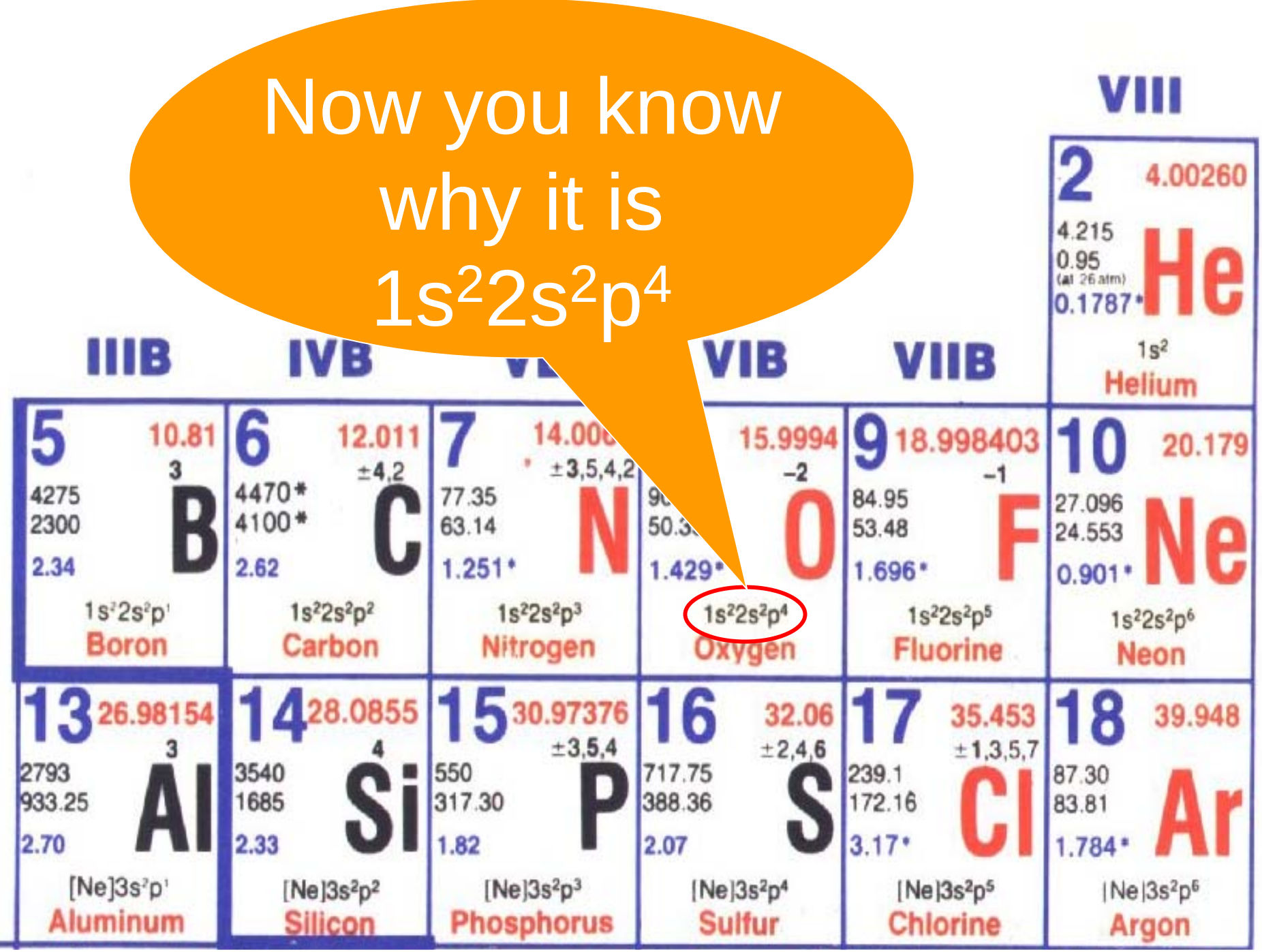
$1s^2 2s^2 2p^3$

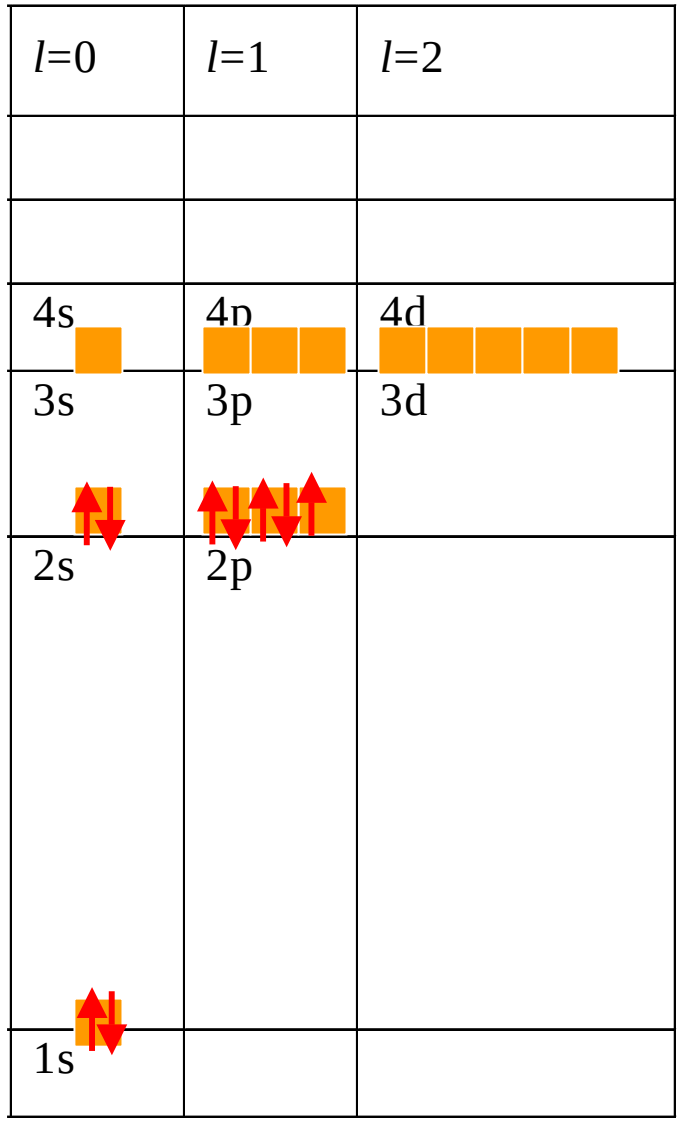


O

$1s^2 2s^2 2p^4$

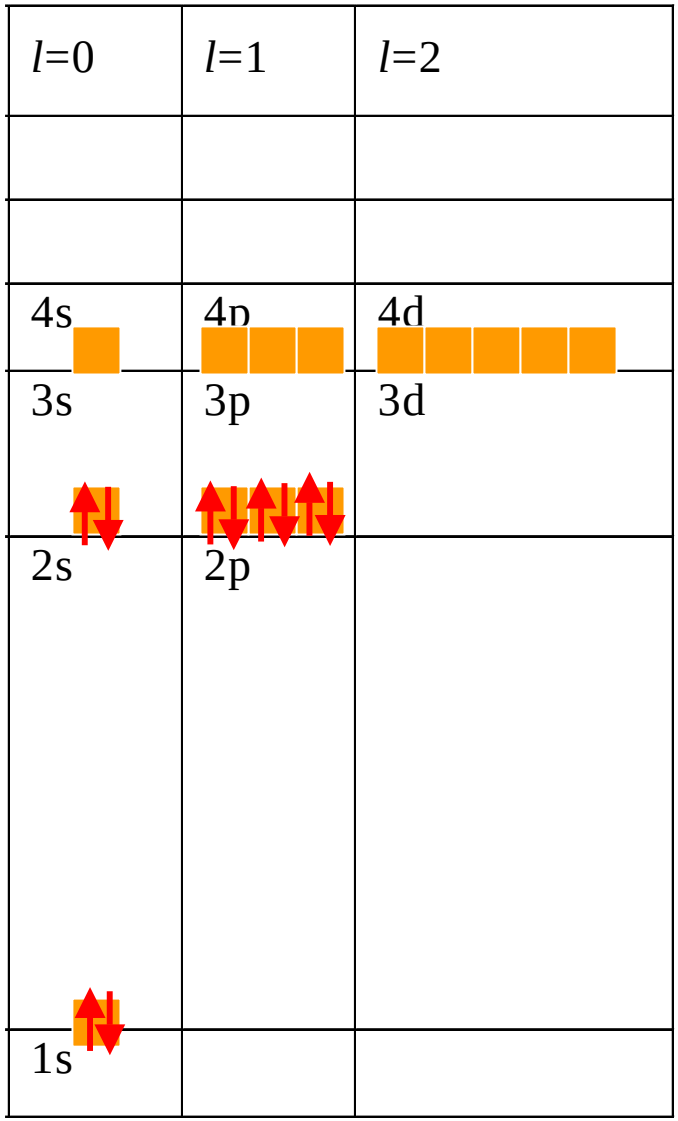
Now you know why it is $1s^2 2s^2 p^4$





F

$1s^2 2s^2 2p^5$



Ne

$1s^2 2s^2 2p^6$

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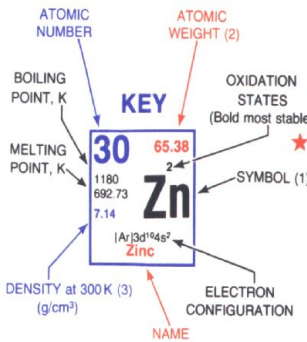
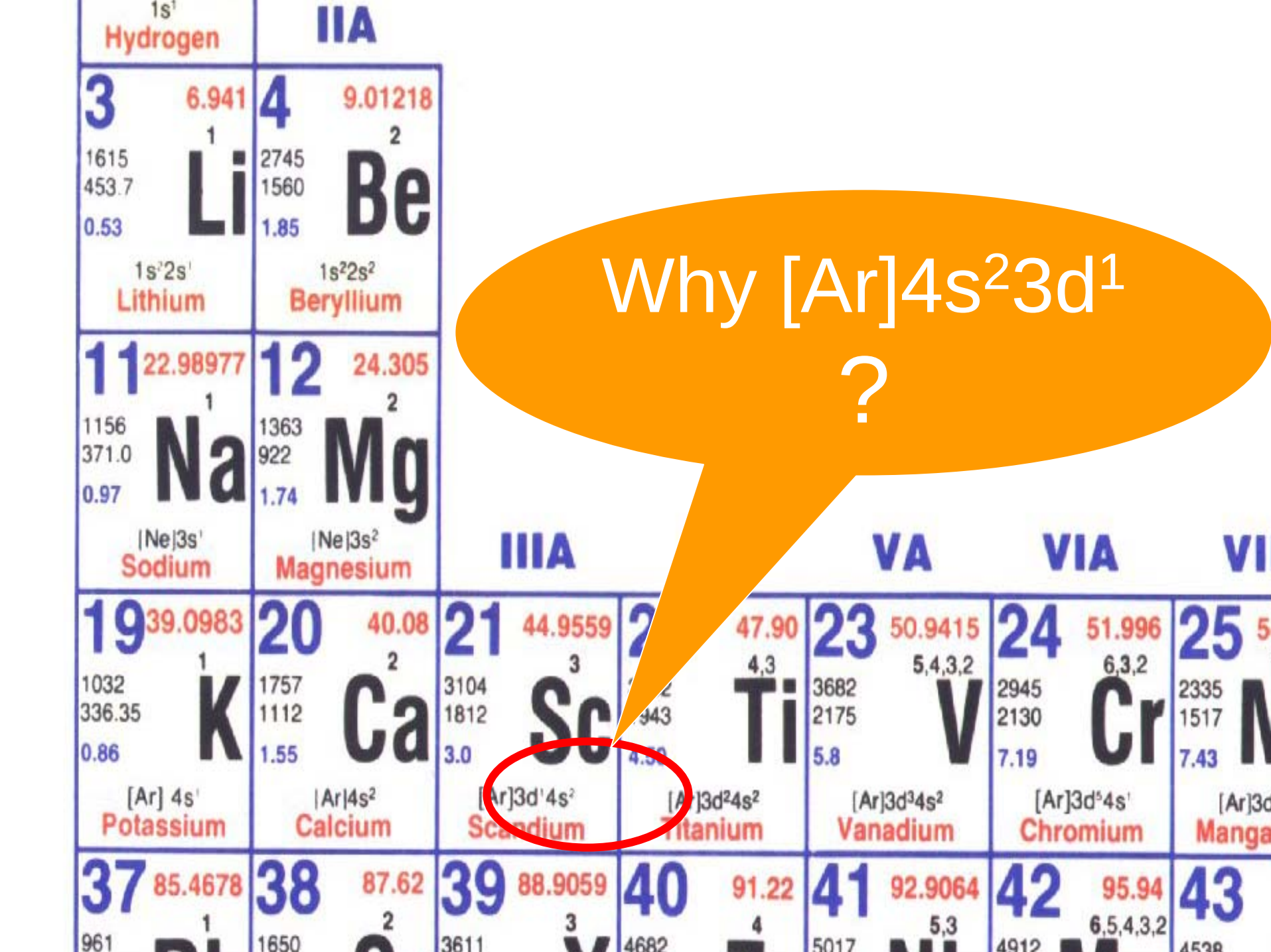
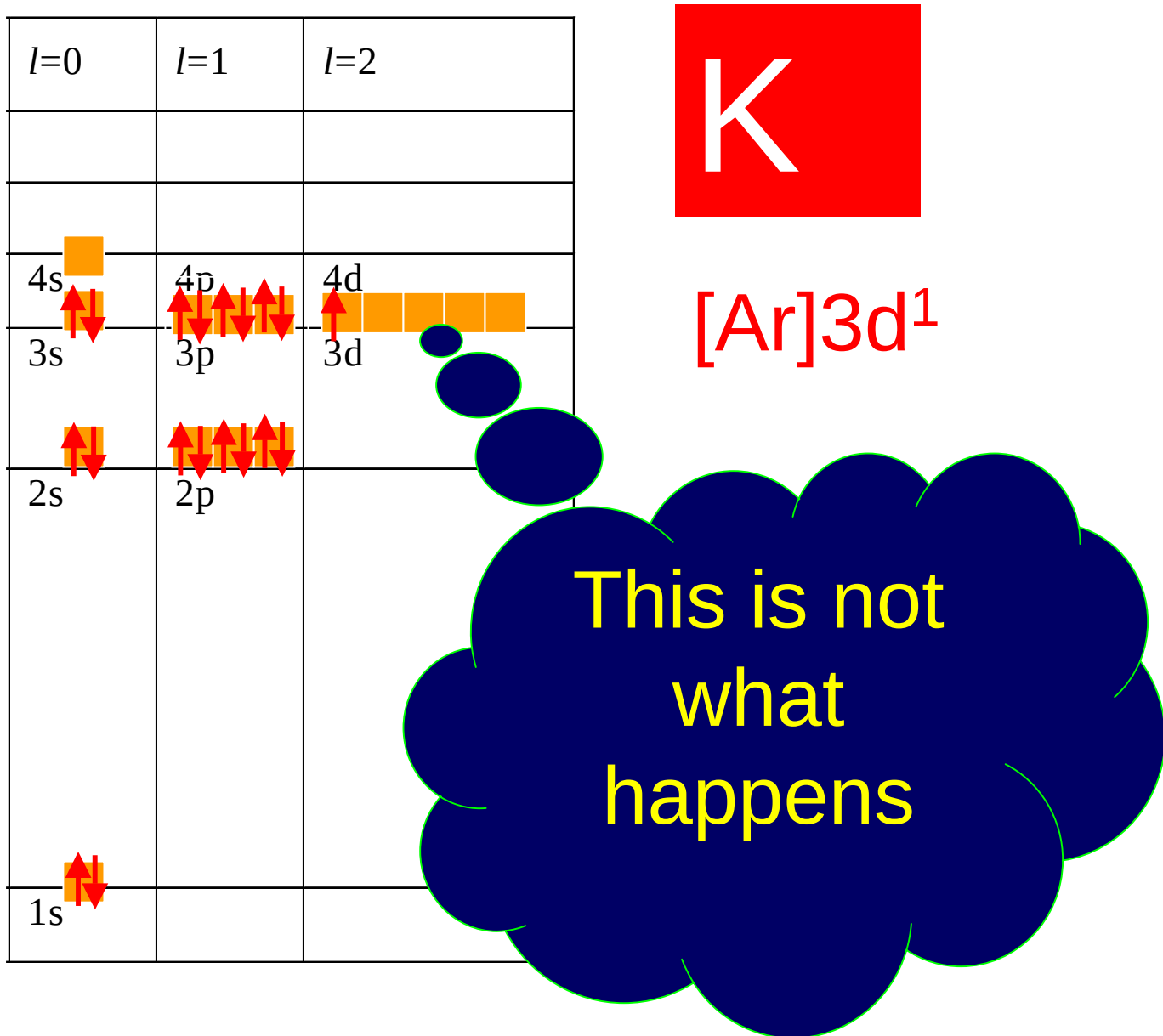
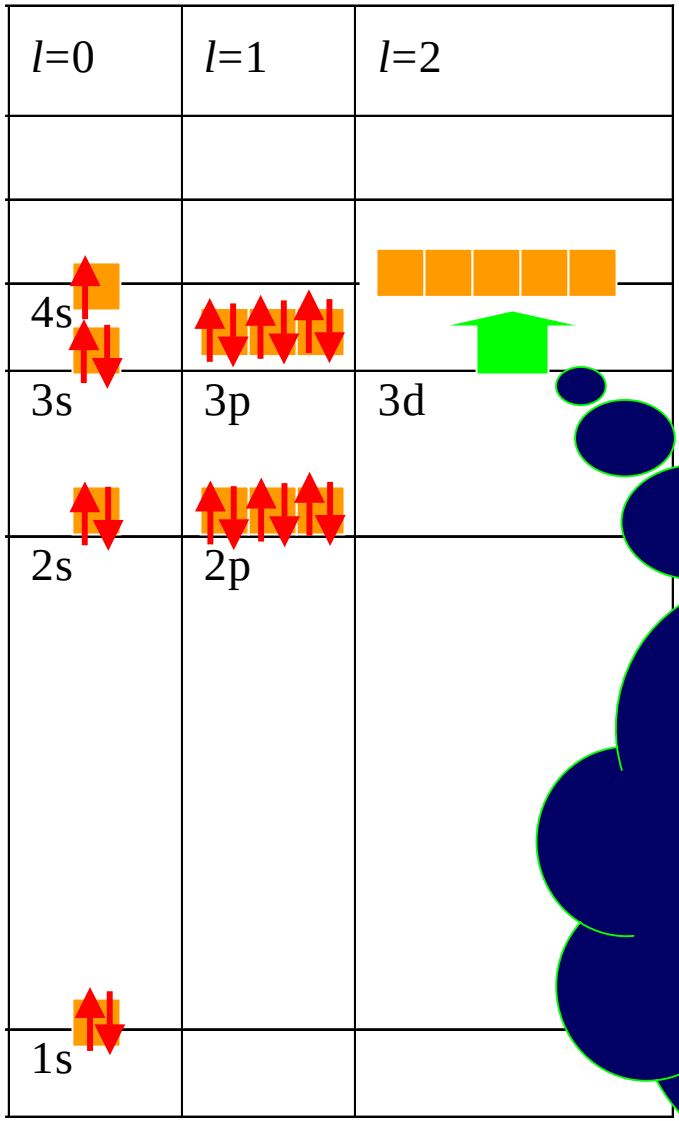



1s¹
Hydrogen
IIA
3 6.941
1
1615
453.7
0.53
Li
1s²2s¹
Lithium
4 9.01218
2
2745
1560
1.85
Be
1s²2s²
Beryllium
11 22.98977
1
1156
371.0
0.97
Na
[Ne]3s¹
Sodium
12 24.305
2
1363
922
1.74
Mg
[Ne]3s²
Magnesium
IIIA
VA
VIA
VI
Why [Ar]4s²3d¹
?
19 39.0983
1
1032
336.35
0.86
K
[Ar] 4s¹
Potassium
20 40.08
2
1757
1112
1.55
Ca
[Ar]4s²
Calcium
21 44.9559
3
3104
1812
3.0
Sc
[Ar]3d¹4s²
Scandium
47.90
4,3
Ti
[Ar]3d²4s²
Titanium
23 50.9415
5,4,3,2
3682
2175
5.8
V
[Ar]3d³4s²
Vanadium
24 51.996
6,3,2
2945
2130
7.19
Cr
[Ar]3d⁵4s¹
Chromium
25
2335
1517
7.43
[Ar]3d
Manga
37 85.4678
1
961
38 87.62
2
1650
39 88.9059
3
3611
40 91.22
4
4682
41 92.9064
5,3
5017
42 95.94
6,5,4,3,2
4912
43
4538

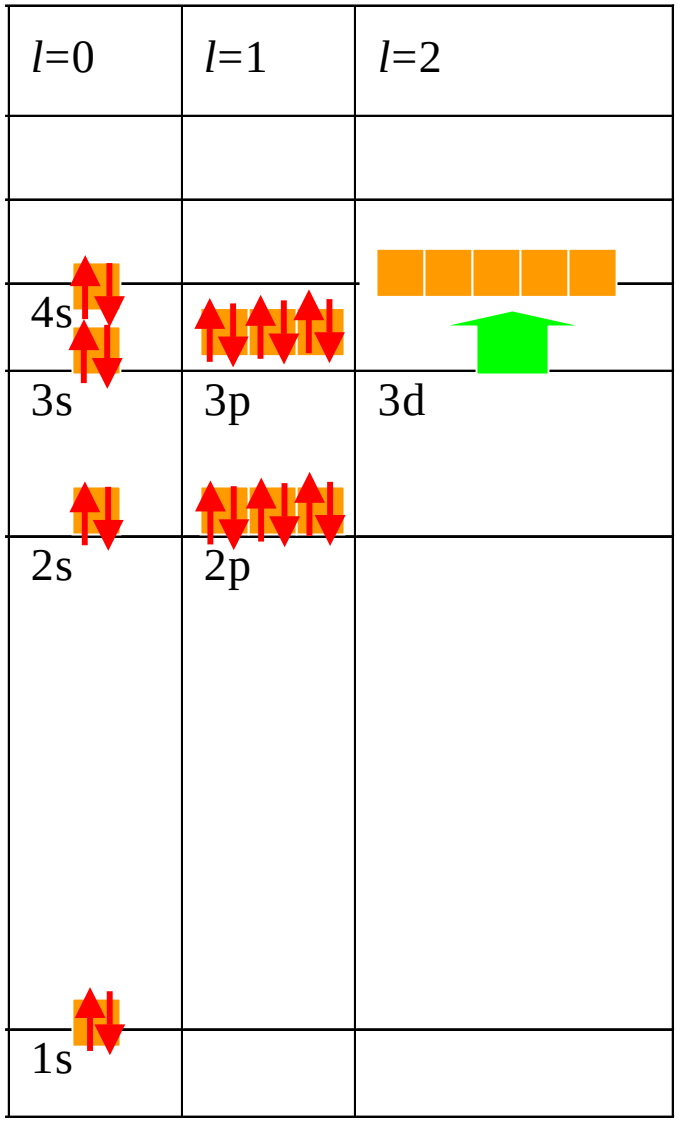

l=0
l=1
l=2
4s
4p
4d
3s
3p
3d
2s
2p
1s
K
[Ar]3d1
This is not what happens



K

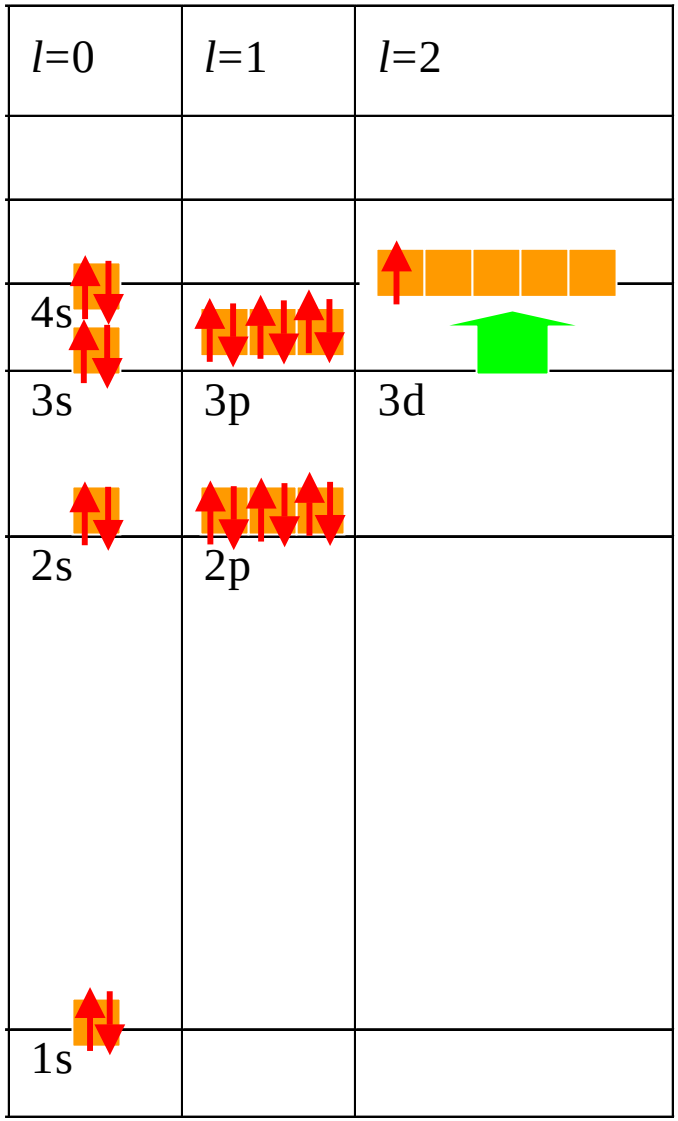
$[Ar]4s^1$

In reality the 3d-states are higher than the 4s



Ca

[Ar]$4s^2$



Sc

$[Ar]4s^2 3d^1$