

Atoms Lecture 4: Electron Configuration

Learning Objective	Openstax 2e Chapter
Electron Spin: A Fourth Quantum Number	<u>6.3</u>
Multielectron Atoms	<u>6.4</u>
The Aufbau Principle	<u>6.4</u>
Electron configurations	<u>6.4</u>

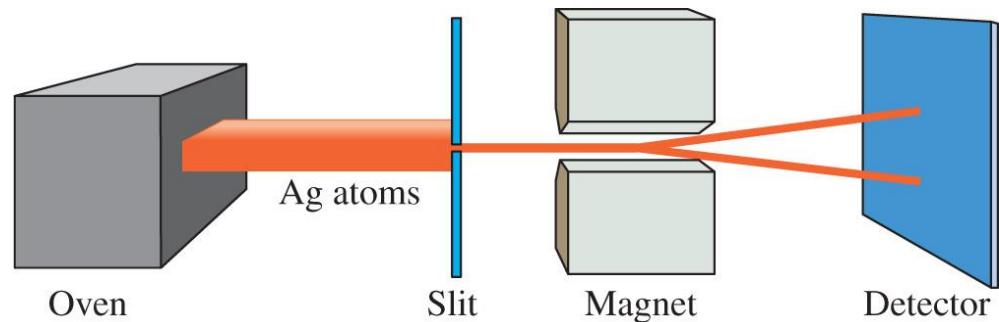
Suggested Practice Problems

[Chapter 6 Exercises](#) – Questions: 49, 53, 55, 57, 59, 63

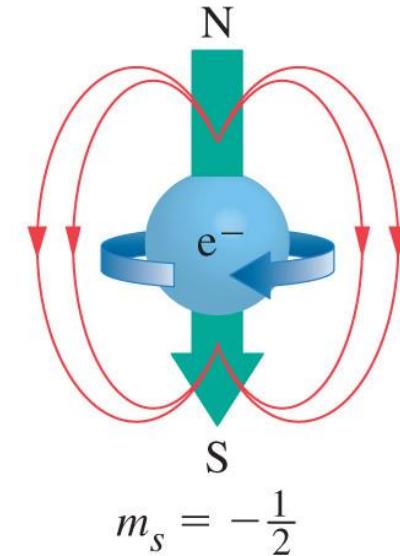
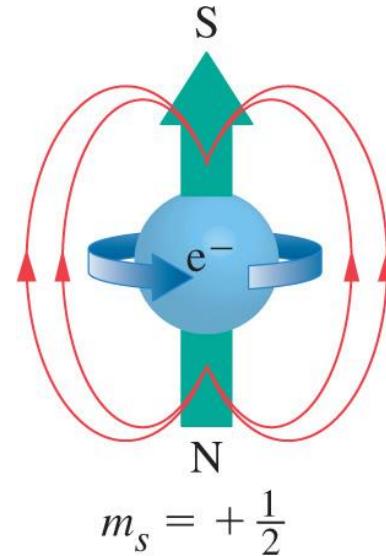
Answers can be found in the [Chapter 6 Answer Key](#)

Electron Spin: A Fourth Quantum Number (m_s)

Some unexplained features of the Hydrogen atom spectrum could be explained assuming that electron spins.



The Stern-Gerlach Experiment (1920) is an evidence that the phenomenon of electron spin exists.



In addition to the (n, ℓ, m_ℓ) quantum numbers, there is a 4th quantum number:

m_s

Electron Spin Quantum Number

- Describes the orientation of the electron spin
- $m_s = +\frac{1}{2}$ or $-\frac{1}{2}$

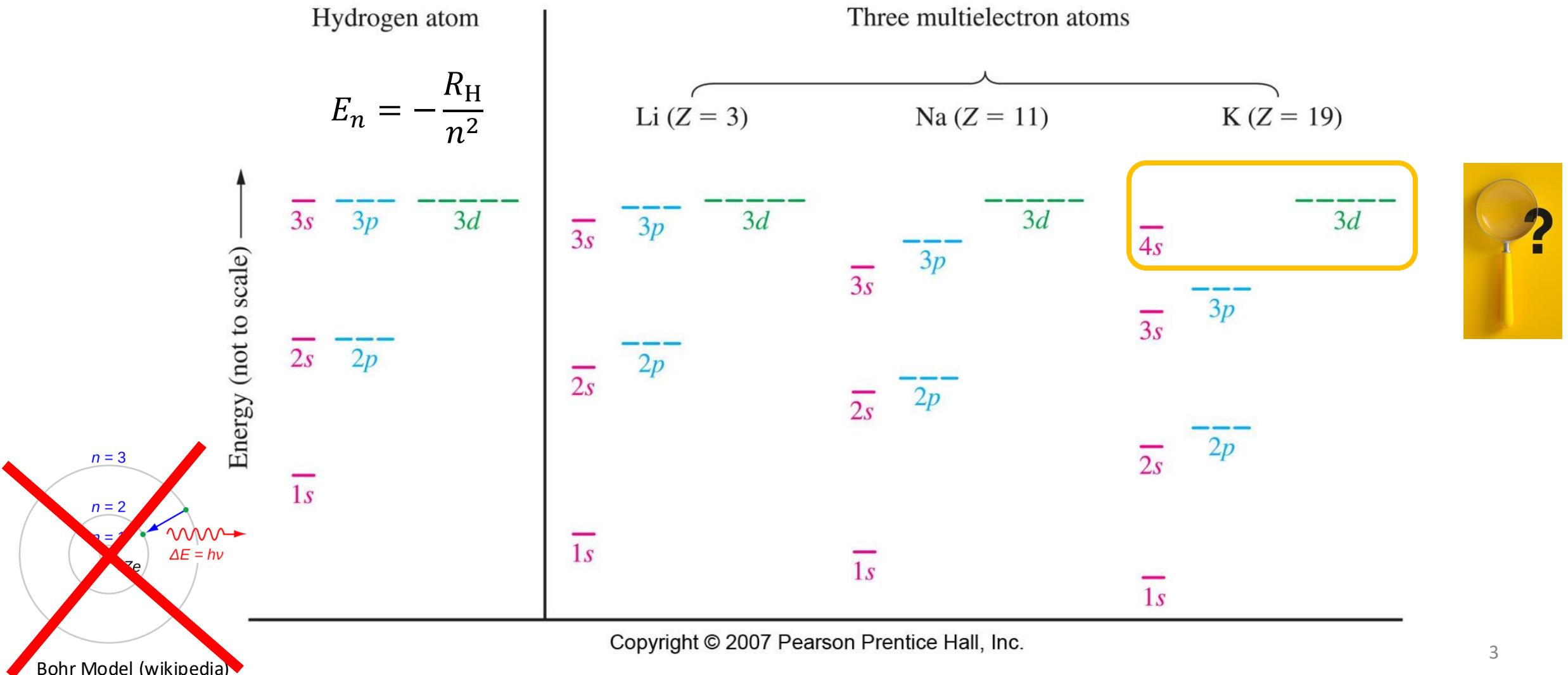
Electron Spin

Pauli Exclusion Principle says that no 2 electrons can have the same set of 4 quantum numbers in an atom.

Multielectron Atoms

The repulsion between electrons means that they stay away from one another in a multielectron atom.

- electrons in orbitals closer to nucleus affect energy of higher orbital electrons
(related to quantum entanglement – see 2022 Nobel Prize)



Penetration and Shielding

Electrons in orbitals closer to the nucleus screen or shield the nucleus from electrons farther away.

- Penetration: ability of electrons in *s*-orbitals that allows them to get close to the nucleus.
 - The *s*-orbitals have a high probability density close to the nucleus (*p*- and *d*-orbitals have zero probability)
 - So, electrons in *s*-orbitals are less screened and (on average) feel greater nuclear attraction.
- The nuclear charge that an electron actually experiences is reduced by intervening electrons to a value of Z_{eff} , called the effective nuclear charge.

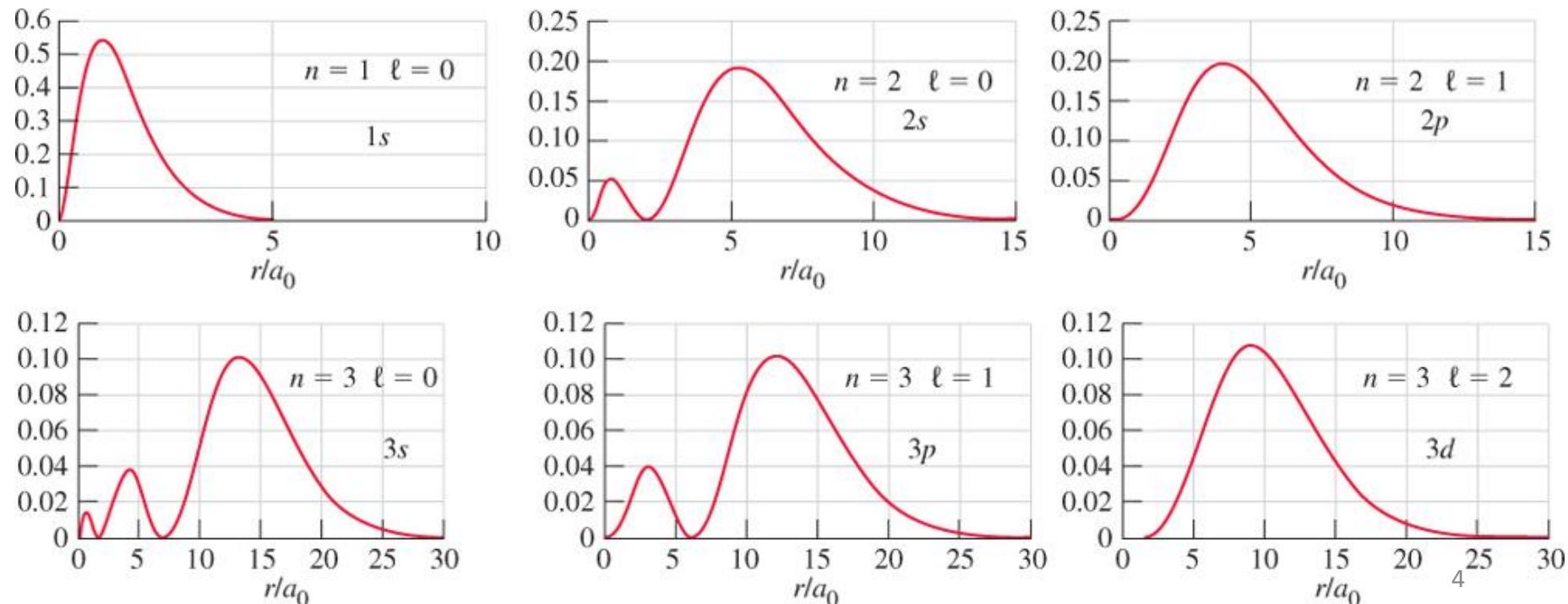


Figure 9: Radial distribution functions: $r^2 R^2(r)$

Electron Configuration

It designates how electrons are distributed among various orbitals in principle shells and subshells.

1. Electrons occupy orbitals in a way that minimizes the energy of the atom.

1s, 2s, 2p, 3s, 3p, **4s**, 3d, 4p, **5s**, 4d, 5p, 6s, **4f**, **5d**, 6p, 7s, **5f**, **6d**, 7p

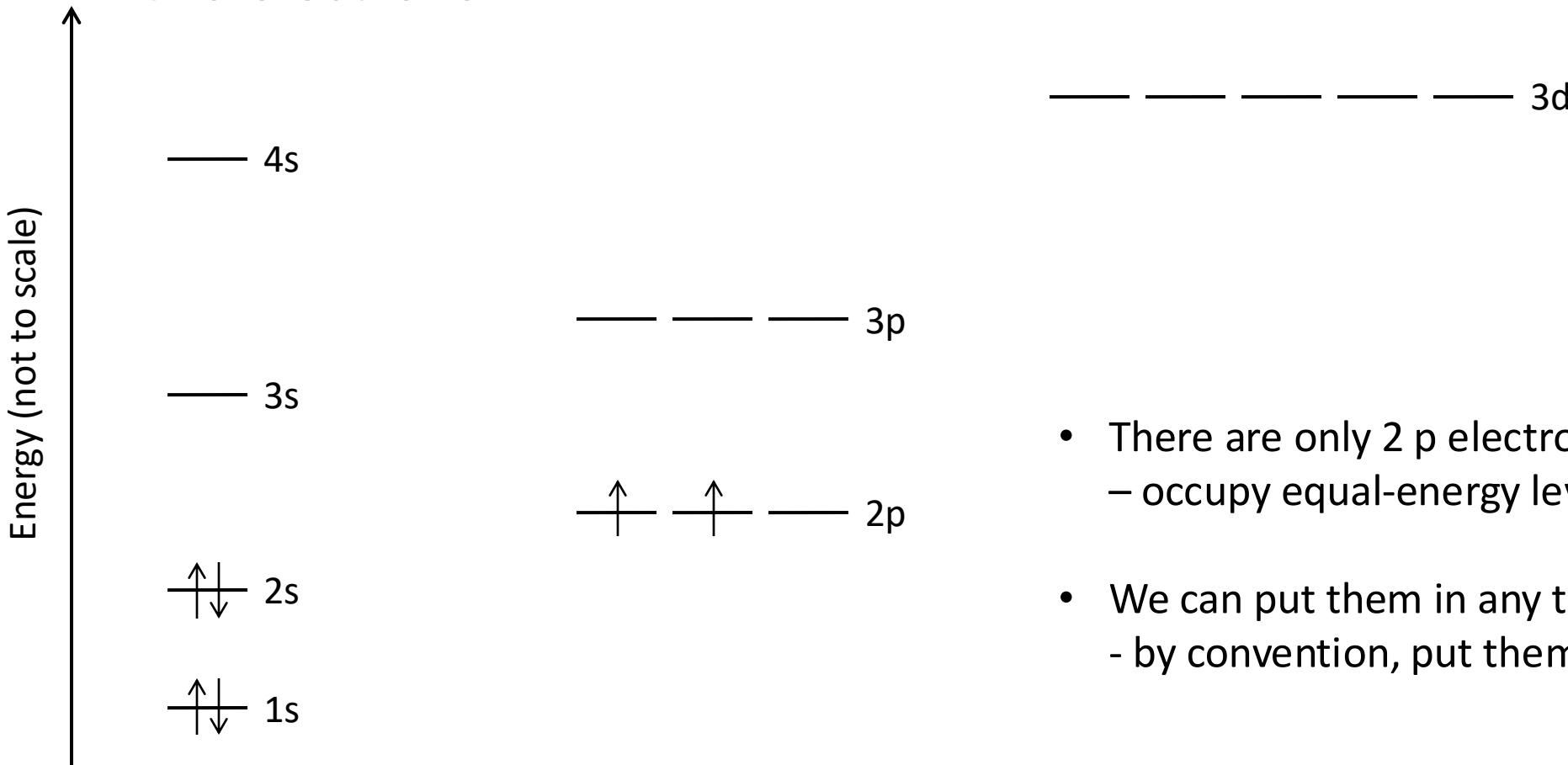
2. Only two electrons may occupy the same orbital, and these electrons must have opposite spin: **Pauli Exclusion Principle**.

$n = 1$	1 s orbital			2 electrons
$n = 2$	1 s orbital	3 p orbitals		8 electrons
$n = 3$	1 s orbital	3 p orbitals	5 d orbitals	18 electrons

3. When orbitals of identical energy (degenerate orbitals) are available, electrons initially occupy these orbitals singly with parallel spins: **Hund's Rule**.

Example: Carbon Atom

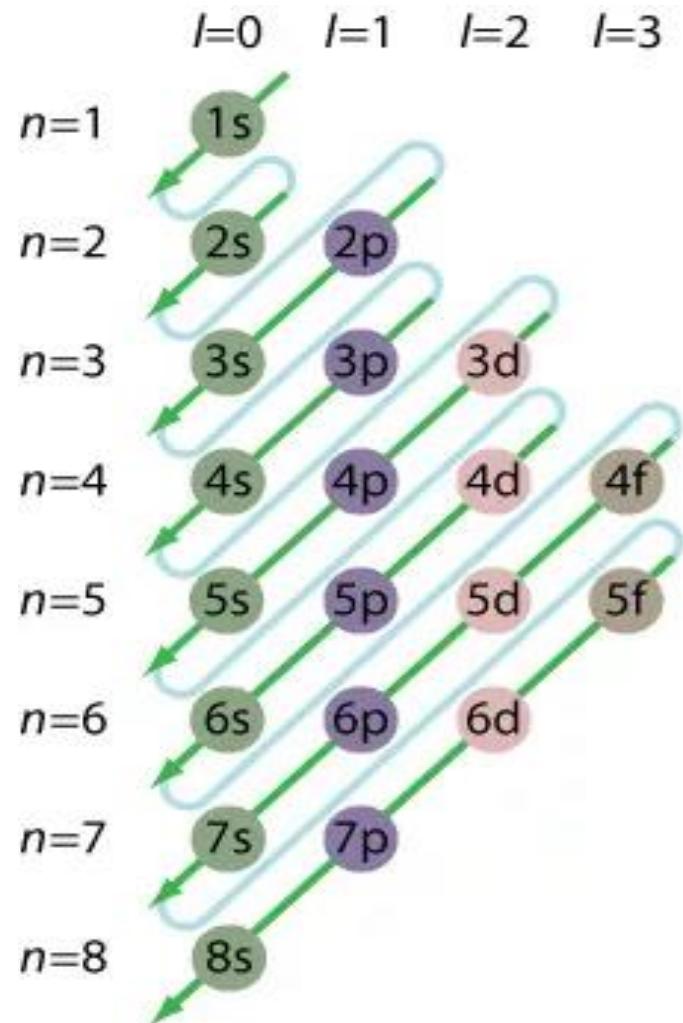
C: 6 electrons



- There are only 2 p electrons
 - occupy equal-energy levels singly (Hund's Rule)
- We can put them in any two 2p orbitals
 - by convention, put them in p_x and p_y first

The Aufbau Process

It designates how electrons are distributed among various orbitals in principle shells and subshells.



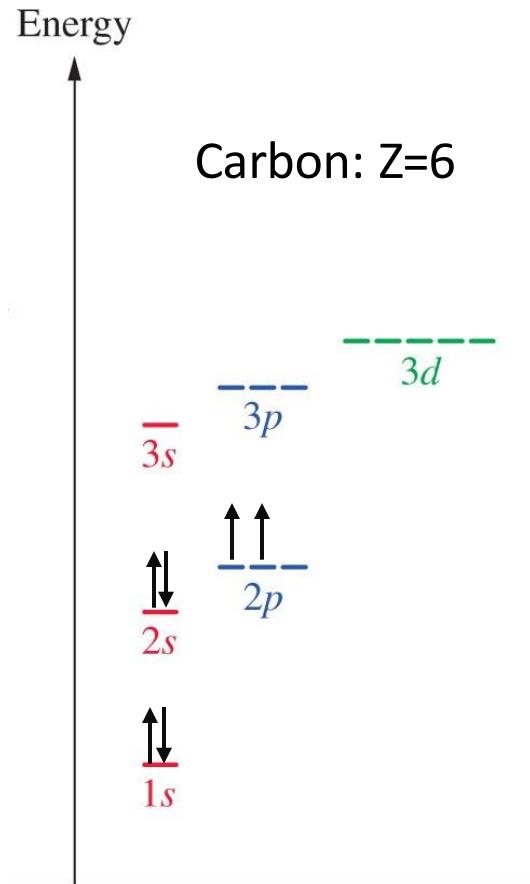
Ground state “Electron Configuration” of first 18 elements in “spdf” notation

H: $1s^1$	Li: $1s^2 2s^1$	Na: $1s^2 2s^2 2p^6 3s^1$
He: $1s^2$	Be: $1s^2 2s^2$	Mg: $1s^2 2s^2 2p^6 3s^2$
	B: $1s^2 2s^2 2p^1$	Al: $1s^2 2s^2 2p^6 3s^2 3p^1$
	C: $1s^2 2s^2 2p^2$	Si: $1s^2 2s^2 2p^6 3s^2 3p^2$
	N: $1s^2 2s^2 2p^3$	P: $1s^2 2s^2 2p^6 3s^2 3p^3$
	O: $1s^2 2s^2 2p^4$	S: $1s^2 2s^2 2p^6 3s^2 3p^4$
	F: $1s^2 2s^2 2p^5$	Cl: $1s^2 2s^2 2p^6 3s^2 3p^5$
	Ne: $1s^2 2s^2 2p^6$	Ar: $1s^2 2s^2 2p^6 3s^2 3p^6$

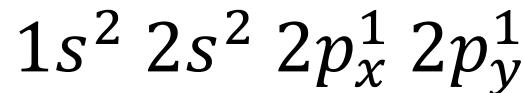
Notations for Electron Configuration

Schemes for writing out electron configurations with different level of detail

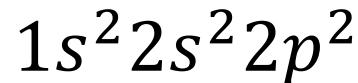
Ground State Electron Configuration of Carbon



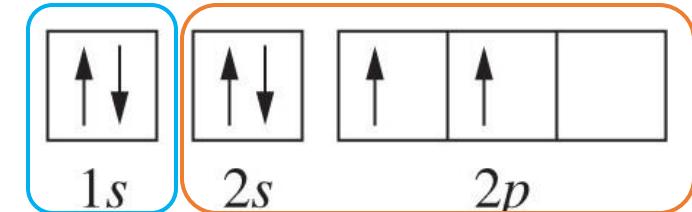
- *spdf* notation (expanded):



- *spdf* notation (condensed):



- Orbital Diagram:

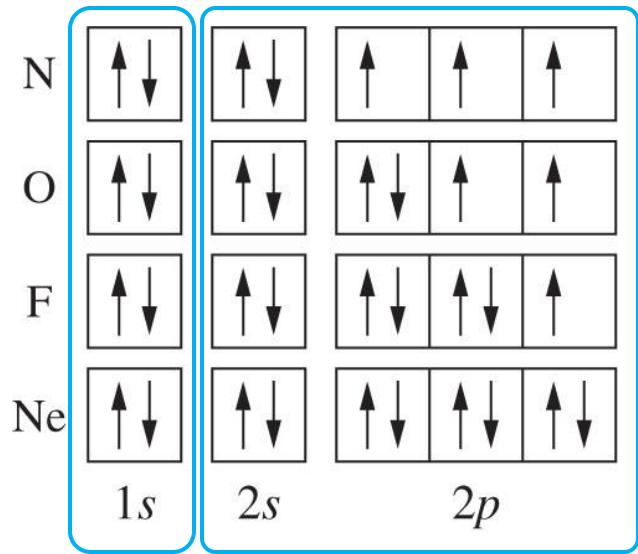


- *spdf* Nobel-gas-core abbreviated notation (condensed):



The Aufbau Process cont.

Filling orbital diagrams through Row 3 and the noble gas abbreviated electron configuration notations



Core Valence

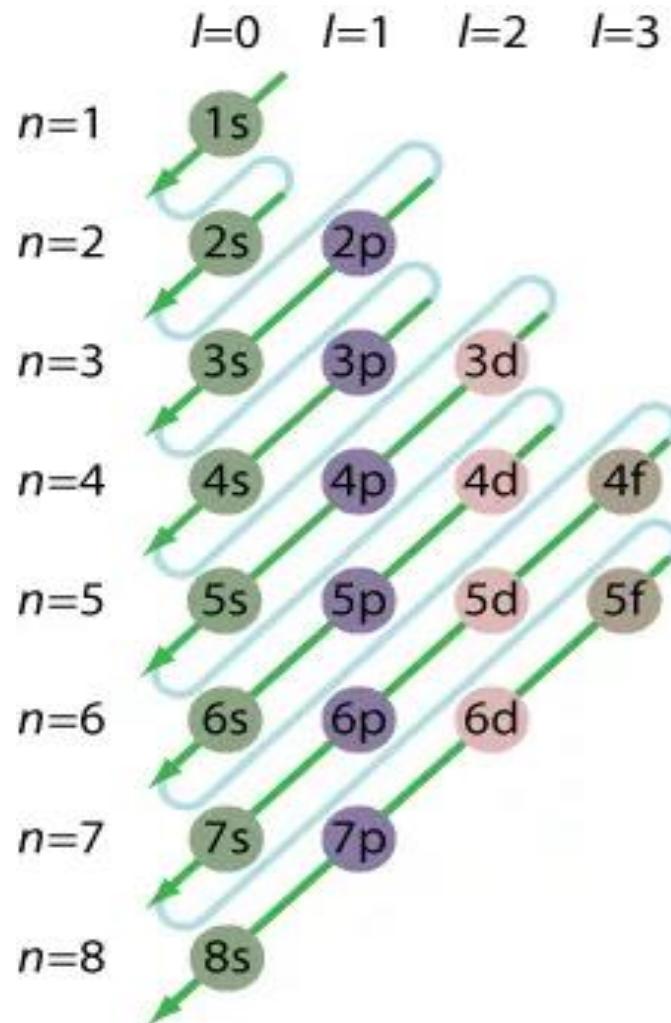


Half-filled subshells and filled subshells have “special stability”.

Sc:	[Ar]		[Ar]3d ¹ 4s ²
Ti:	[Ar]		[Ar]3d ² 4s ²
V:	[Ar]		[Ar]3d ³ 4s ²
Cr:	[Ar]		[Ar]3d ⁵ 4s ¹
Mn:	[Ar]		[Ar]3d ⁵ 4s ²
Fe:	[Ar]		[Ar]3d ⁶ 4s ²
Co:	[Ar]		[Ar]3d ⁷ 4s ²
Ni:	[Ar]		[Ar]3d ⁸ 4s ²
Cu:	[Ar]		[Ar]3d ¹⁰ 4s ¹
Zn:	[Ar]		[Ar]3d ¹⁰ 4s ²

Electron Configuration & The Periodic Table

Elements in the same group of the table have similar electron configurations.



<https://www.thoughtco.com/>

Main-group elements																							
s block		Transition elements														p block							
1	2	3s		3p		3d		4s		4p		4d		4f		13	14	15	16	17	18		
H	He	Li	Be	Na	Mg	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	B	C	N	O	F	Ne
1	2	3	4	11	12	19	20	21	22	23	24	25	26	27	28	29	30	13	14	15	16	17	18
																		Al	Si	P	S	Cl	Ar
																		31	32	33	34	35	36
																		Ga	Ge	As	Se	Br	Kr
																		49	50	51	52	53	54
																		In	Sn	Sb	Te	I	Xe
																		81	82	83	84	85	86
																		Tl	Pb	Bi	Po	At	Rn
																		114	116	117	118	119	120
																		Fl	Lv				

Inner-transition elements															
*	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
†	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Example

Write the noble-gas-core-abbreviated electron configuration of the following atoms?

- Argon ($Z=18$)

$[\text{Ne}]3s^23p^6$

- Calcium ($Z=20$)

$[\text{Ar}]4s^2$

- Bismuth ($Z=83$)

$[\text{Xe}]6s^24f^{14}5d^{10}6p^3$

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H 1.00794	2 Be 9.01218	3 Li 6.941	4 Be 9.01218	5 Na 22.9898	6 Mg 24.3050	7 Al 26.9815	8 Si 10.811	9 P 12.011	10 S 14.0067	11 Cl 15.9994	12 Ar 18.9984	13 Ne 20.1797	14 He 4.00260	15 F 10.00	16 O 15.9994	17 N 18.9984	18 Ne 20.1797
19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.9961	25 Mn 54.9381	26 Fe 55.847	27 Co 58.9332	28 Ni 58.693	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.868	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.757	52 Te 127.60	53 I 126.904	54 Xe 131.29
55 Cs 132.905	56 Ba 137.327	57 *La 138.906	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
Lanthanum 57 La 138.905	Cerium 58 Ce 140.116	Praseodymium 59 Pr 140.908	Neodymium 60 Nd 144.242	Promethium 61 Pm [145]	Samarium 62 Sm 150.36	Europium 63 Eu 151.964	Gadolinium 64 Gd 157.25	Terbium 65 Tb 158.925	Dysprosium 66 Dy 162.500	Holmium 67 Ho 164.930	Erbium 68 Er 167.259	Thulium 69 Tm 168.934	Ytterbium 70 Yb 173.054	Lutetium 71 Lu 174.967			