

# Atoms Lecture 4: Electron Configuration

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

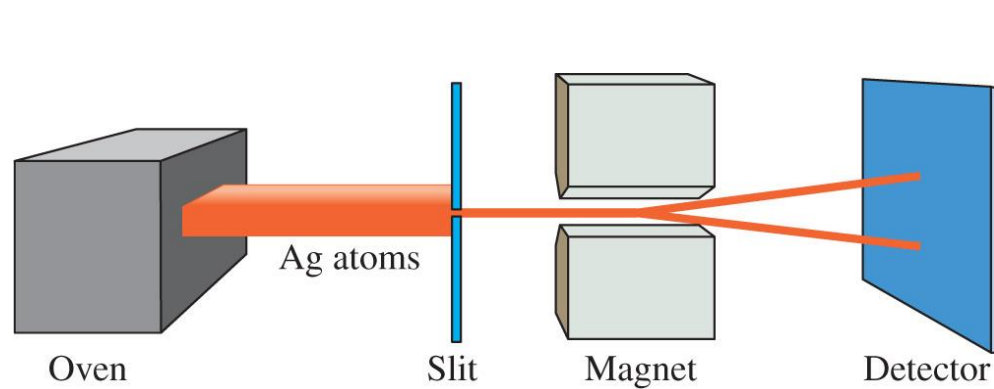
## Suggested Practice Problems

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

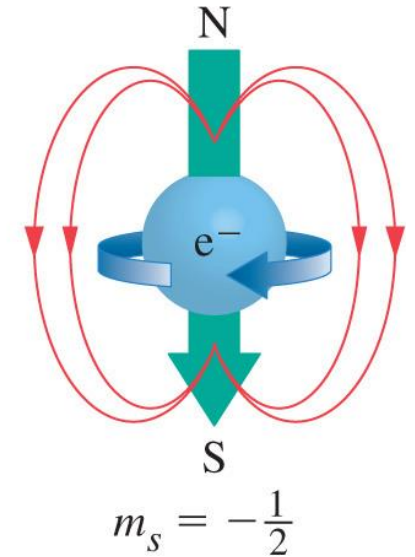
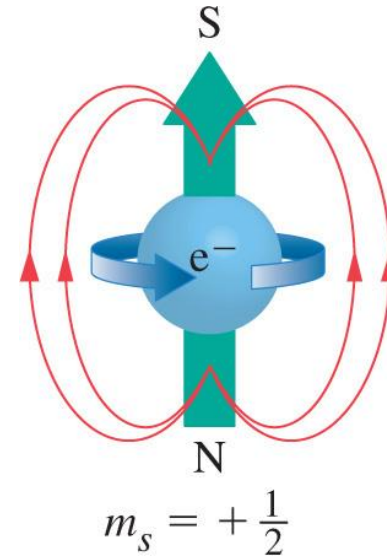
Answers can be found in the [Chapter 6 Answer Key](#)

# 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  $(n, \ell, m_\ell)$  quantum numbers, there is a 4<sup>th</sup> quantum number:

$m_s$  →

Electron Spin Quantum Number

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

→

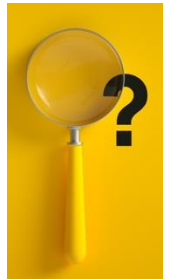
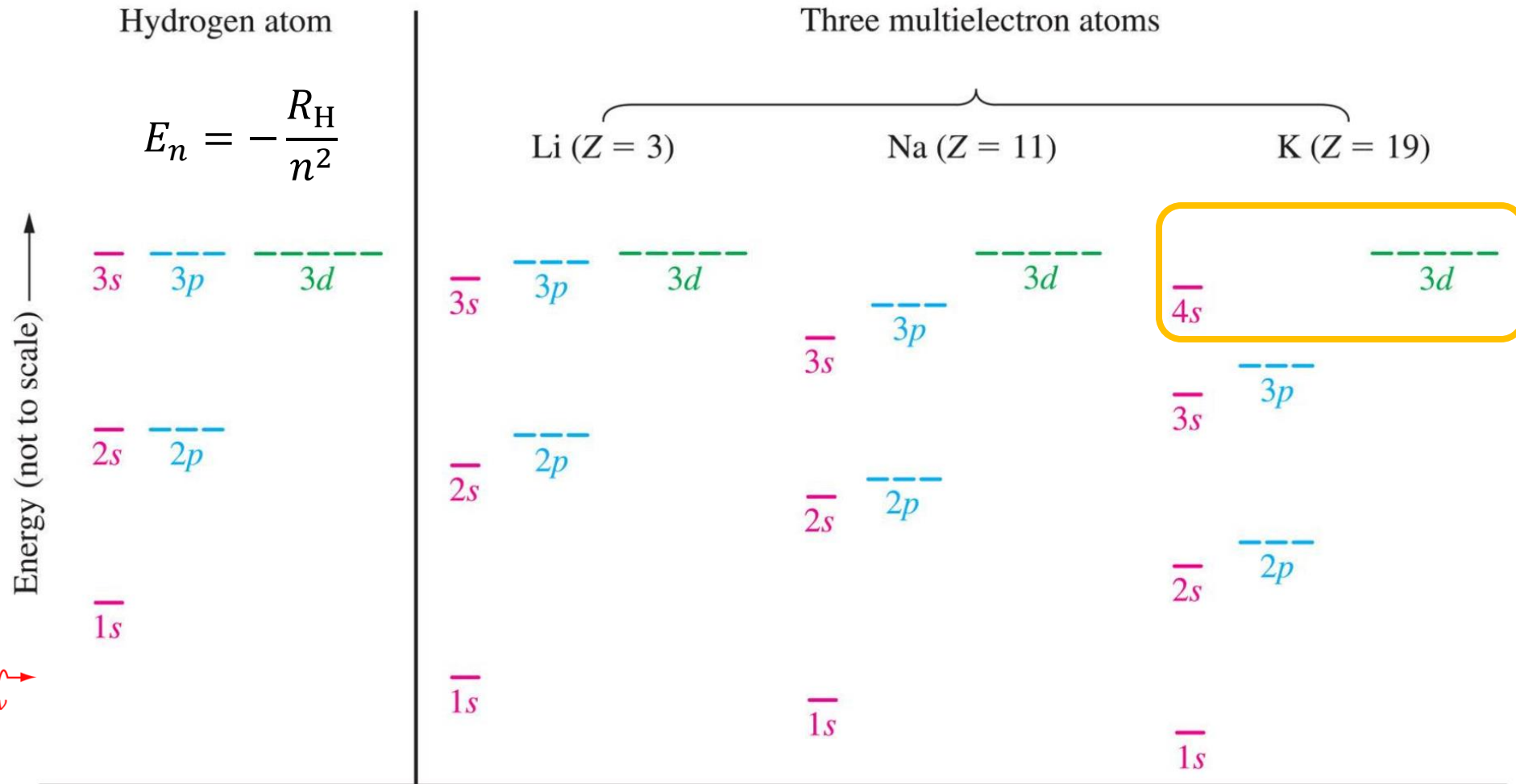
Electron Spin

**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.

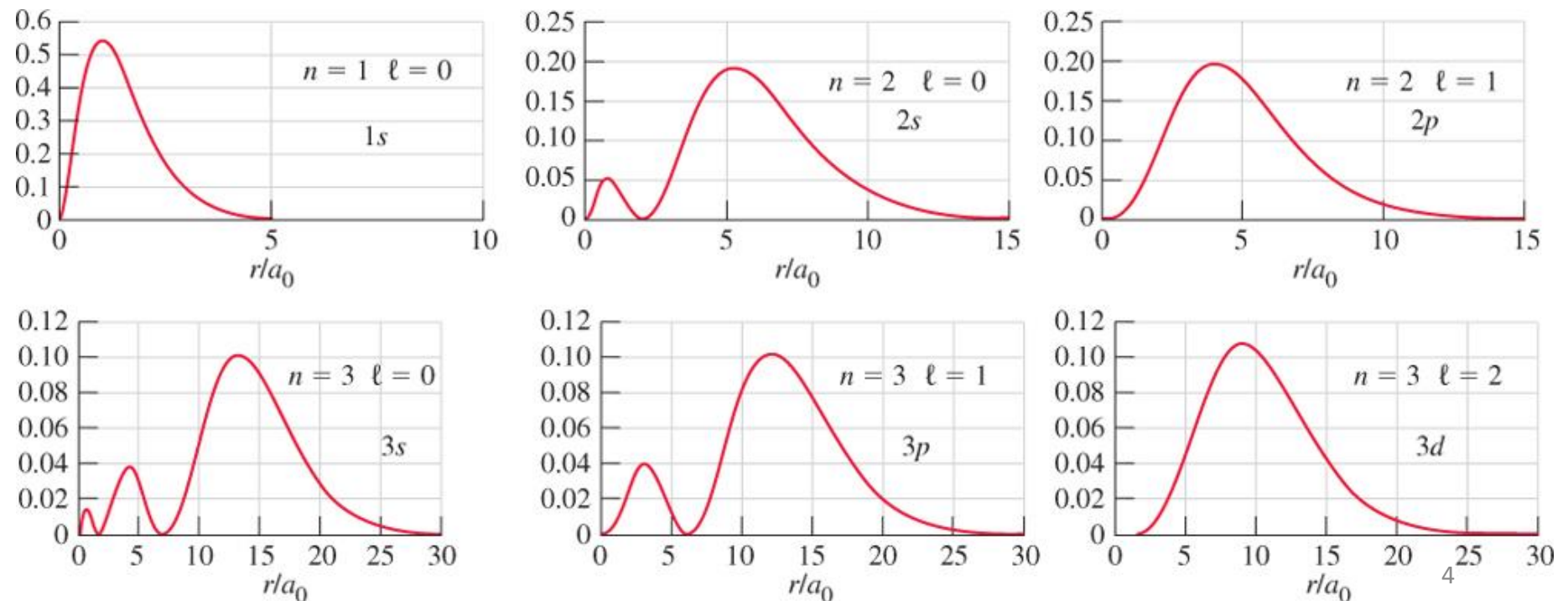
- electrons in orbitals closer to nucleus affect energy of higher orbital electrons  
(related to quantum entanglement – see 2022 Nobel Prize)



# 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  $Z_{\text{eff}}$ , 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.

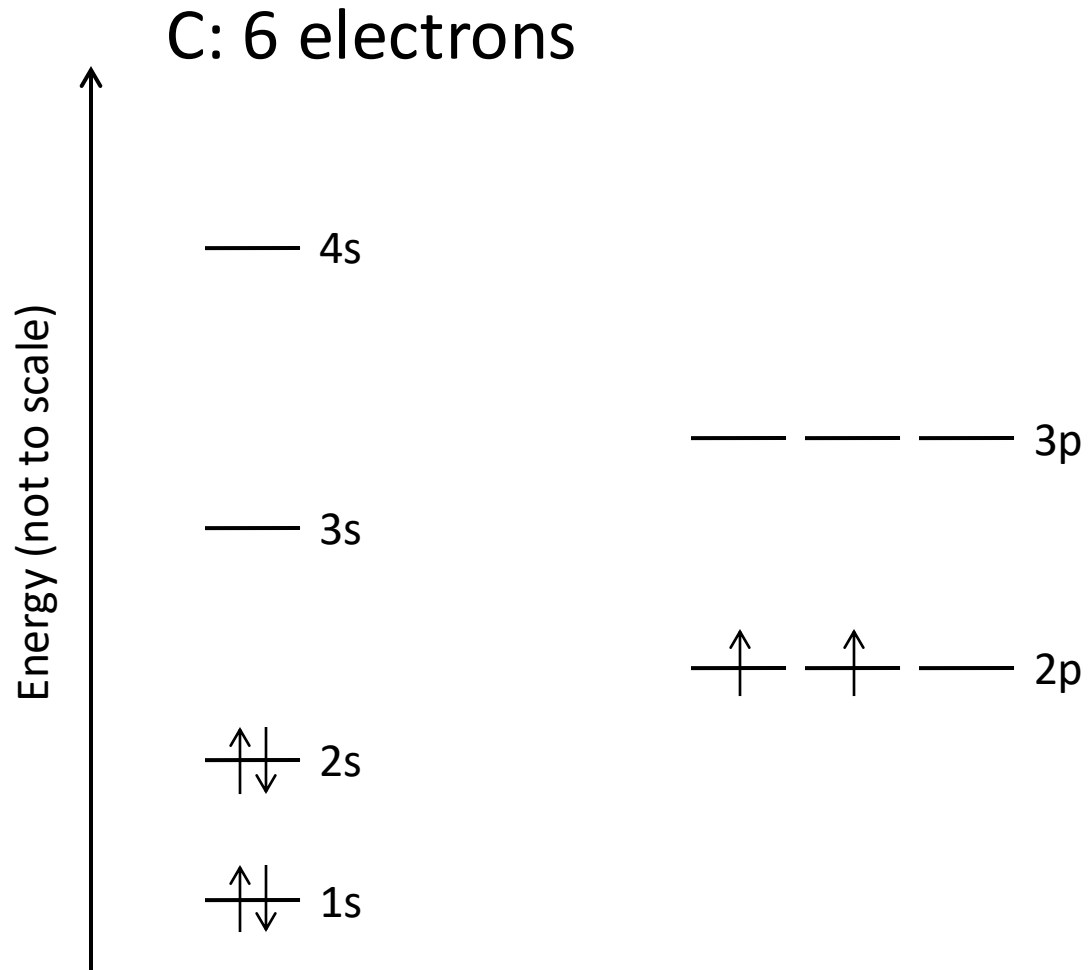
1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, 7p

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

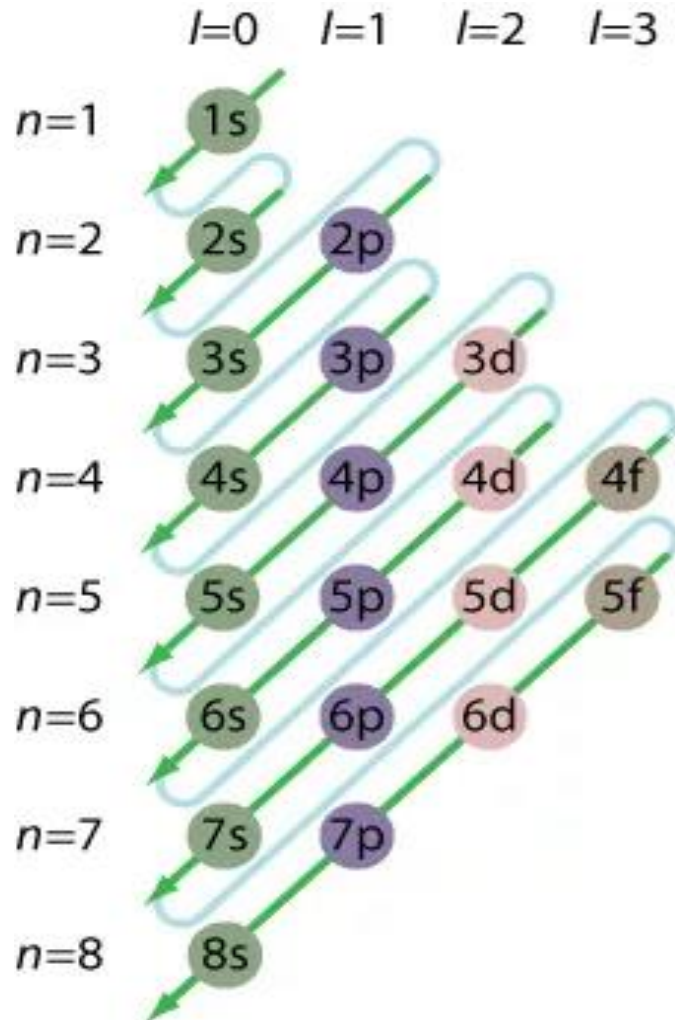


\_\_\_\_\_ 3d

- 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.



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

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

H:  $1s^1$

He:  $1s^2$

Li:  $1s^2 2s^1$

Be:  $1s^2 2s^2$

B:  $1s^2 2s^2 2p^1$

C:  $1s^2 2s^2 2p^2$

N:  $1s^2 2s^2 2p^3$

O:  $1s^2 2s^2 2p^4$

F:  $1s^2 2s^2 2p^5$

Ne:  $1s^2 2s^2 2p^6$

Na:  $1s^2 2s^2 2p^6 3s^1$

Mg:  $1s^2 2s^2 2p^6 3s^2$

Al:  $1s^2 2s^2 2p^6 3s^2 3p^1$

Si:  $1s^2 2s^2 2p^6 3s^2 3p^2$

P:  $1s^2 2s^2 2p^6 3s^2 3p^3$

S:  $1s^2 2s^2 2p^6 3s^2 3p^4$

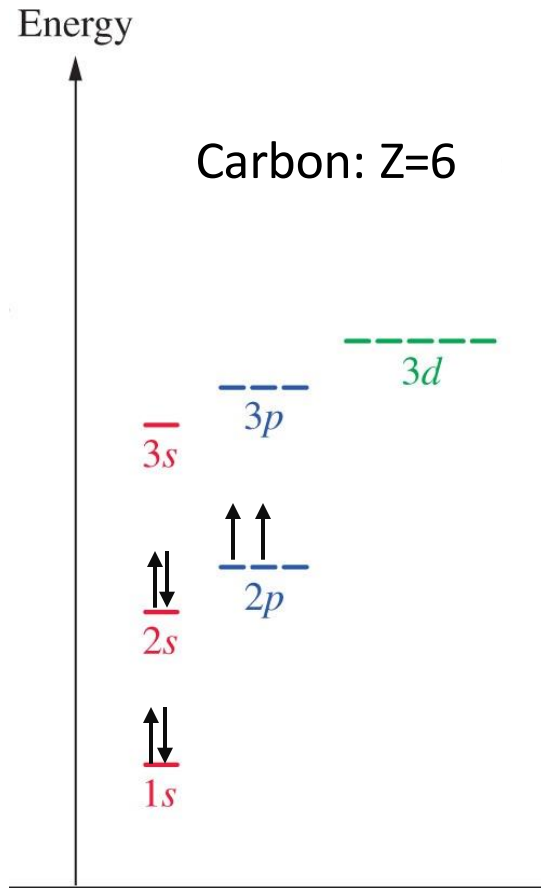
Cl:  $1s^2 2s^2 2p^6 3s^2 3p^5$

Ar:  $1s^2 2s^2 2p^6 3s^2 3p^6$

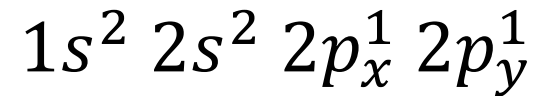
# Notations for Electron Configuration

Schemes for writing out electron configurations with different level of detail

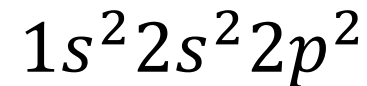
## Ground State Electron Configuration of Carbon



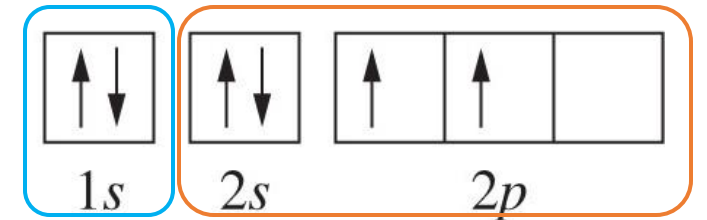
- spdf* notation (expanded):



- spdf* notation (condensed):



- Orbital Diagram:



Core: [He]

Valence

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





# The Aufbau Process cont.

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

N	
O	
F	
Ne	
	1s      2s      2p

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

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

[He]  $2s^2 2p^5$

[He]  $2s^2 2p^6$

**Core**      **Valence**  
[He]:  $1s^2$

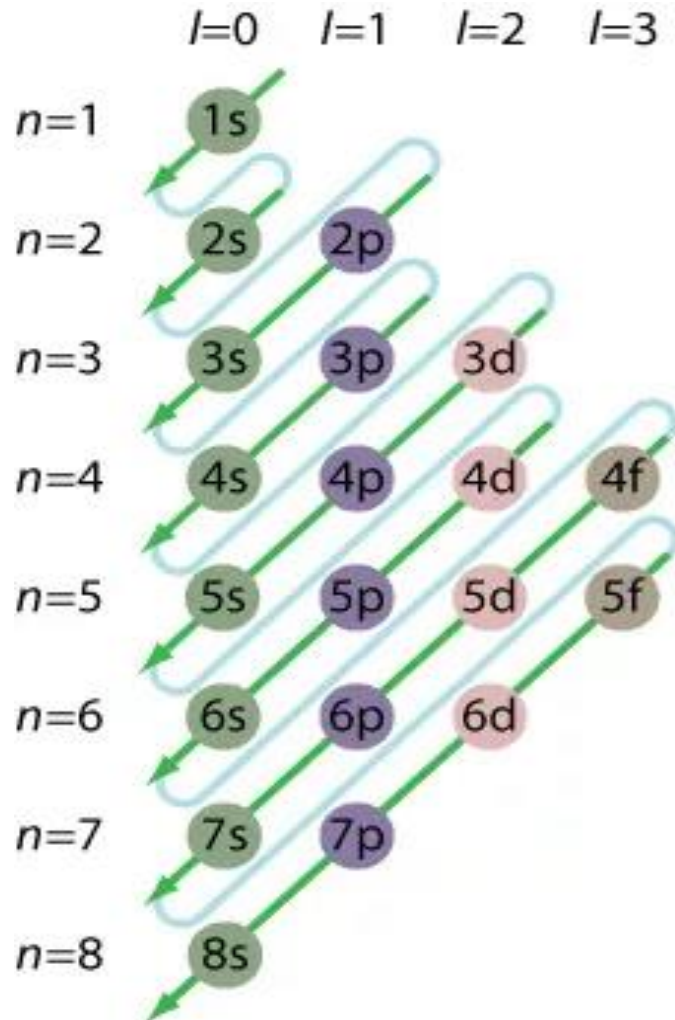
[Ar]:  $1s^2 2s^2 2p^6 3s^2 3p^6$

**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] $3d^{10} 4s^2$
		3d      4s	

# 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																p block	
1	2															13	18
1s H	2s He															5 B	10 Ne
3 Li	4 Be															6 C	17 F
11 Na	12 Mg															7 N	18 Ar
																8 O	
																9 F	
																15 P	
																16 S	
																17 Cl	
																18 Ar	
																31 Ga	36 Kr
																32 Ge	35 Br
																33 As	34 Se
																34 S	35 Br
																35 Cl	36 Kr
																49 In	54 Xe
																50 Sn	53 I
																51 Sb	54 Xe
																52 Te	53 I
																53 Br	54 Xe
																54 Kr	55 Rn
																81 Tl	86 Rn
																82 Pb	85 At
																83 Bi	86 Rn
																84 Po	85 At
																85 Fr	86 Rn
																86 Rn	87 Fr
																87 Fr	88 Ra
																88 Ra	89 Ac
																89 Ac	90 Th
																90 Th	91 Pa
																91 Pa	92 U
																92 U	93 Np
																93 Np	94 Pu
																94 Pu	95 Am
																95 Am	96 Cm
																96 Cm	97 Bk
																97 Bk	98 Cf
																98 Cf	99 Es
																99 Es	100 Fm
																100 Fm	101 Md
																101 Md	102 No
																102 No	103 Lr
																103 Lr	

## Example

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

- Argon (Z=18)



- Calcium ( $Z=20$ )



- Bismuth ( $Z=83$ )



1 1A																	18 8A
1 H 1.00794	2 2A											13 3A	14 4A	15 5A	16 6A	17 7A	2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.811	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.1797
11 Na 22.9898	12 Mg 24.3050	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B		10 10B	11 1B	12 2B	13 Al 26.9815	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
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)
<div>Lanthanum 57 La 138.905</div>																	