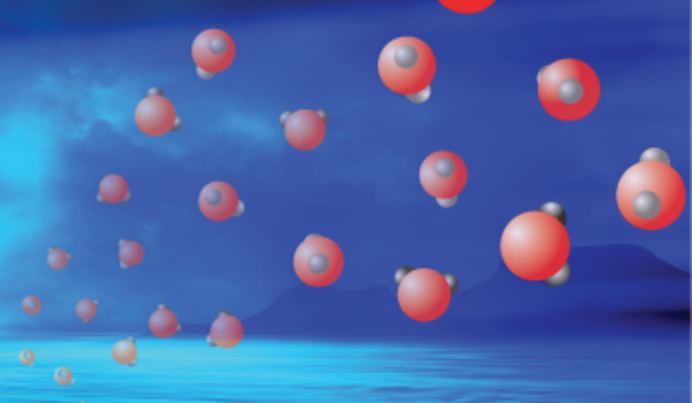


Chapter 4 Modern Atomic Theory

An Introduction to Chemistry
by Mark Bishop

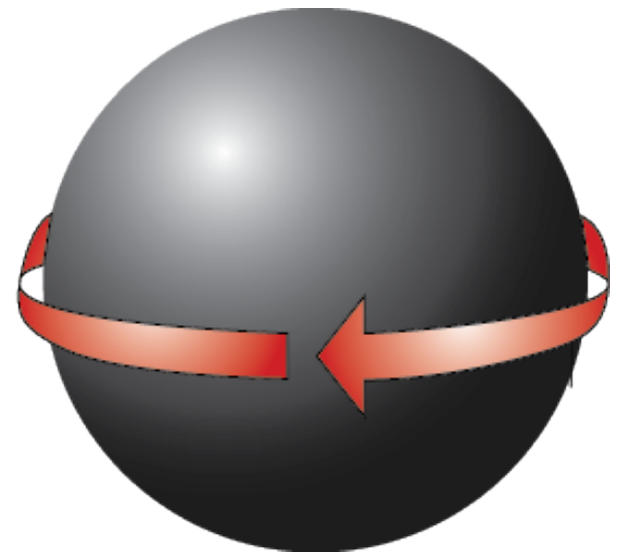
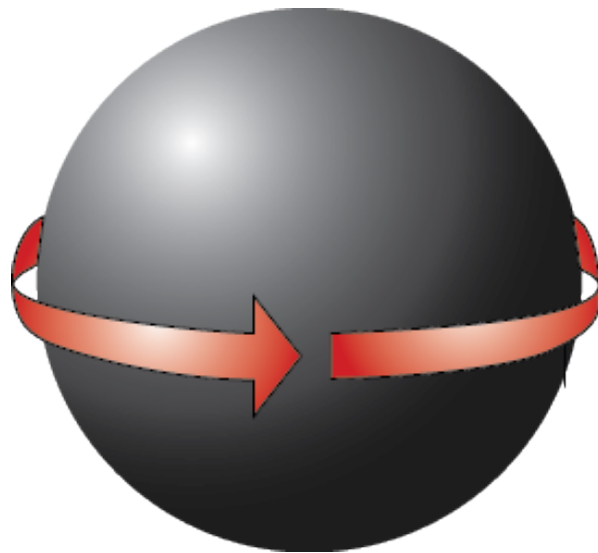
Orbitals for Ground States of Known Elements



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

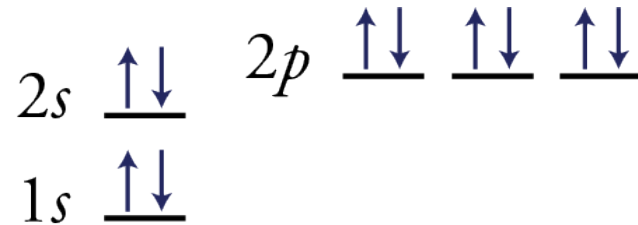
No other orbitals are necessary for describing the electrons of the known elements in their ground states.

Electron Spin



Pauli Exclusion Principle

- *No two electrons in an atom can have the same unique set of four quantum numbers.*
- The first quantum number describes the principal energy level. For example, the quantum number 2 identifies the second principal energy level.



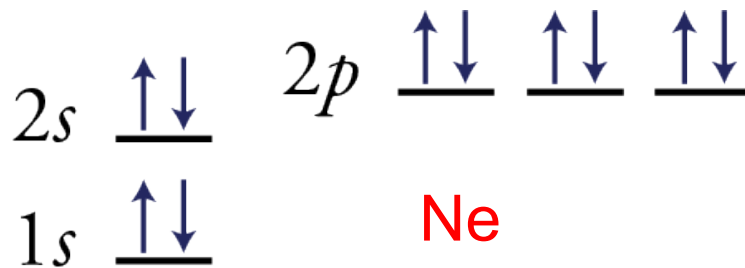
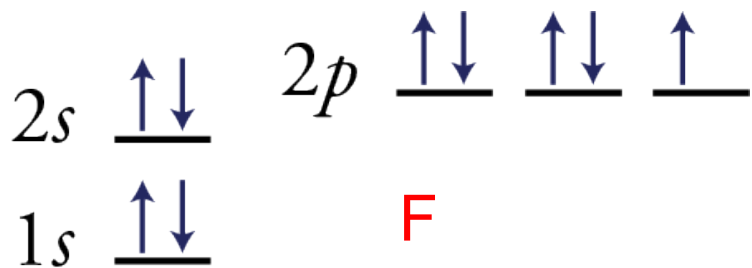
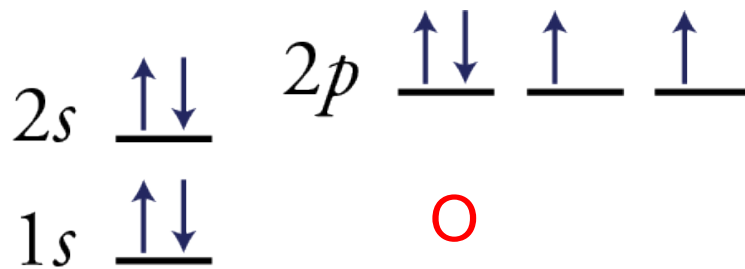
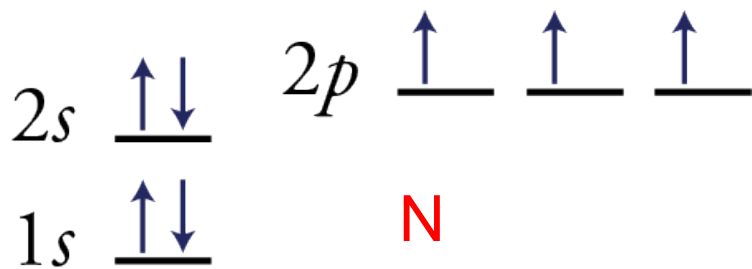
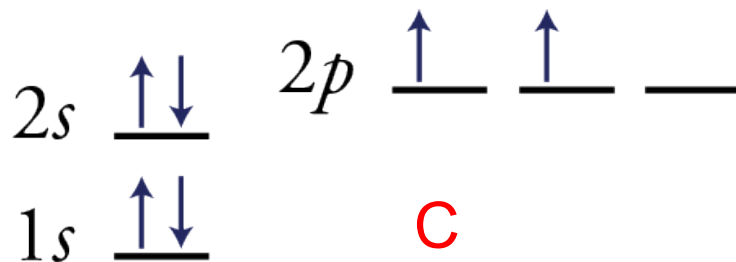
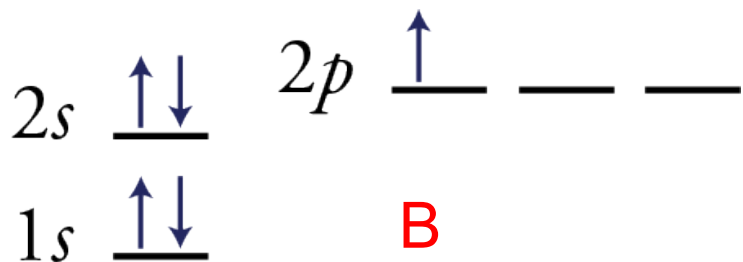
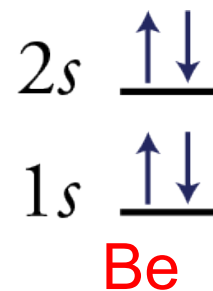
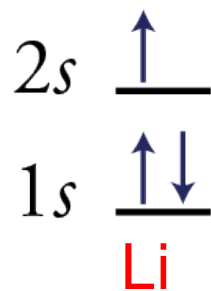
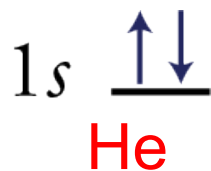
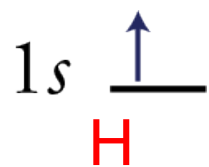
- The first two quantum numbers together describe a sublevel. For example, 2,1 describes the 2p sublevel.
- The first three quantum numbers describe an orbital. For example, 2,1,1 describes one of the 2p orbitals.
- It takes all four quantum numbers to describe an electron. For example, 2,1,1,+1/2 describes an electron in a 2p orbital.

Pauli Exclusion Principle



- No two electrons in an atom can be in the same principal energy level, the same sublevel, the same orbital, and with the same spin.
- This means that electrons in the same orbital must have opposite spin.
- Because there are only two possible spins, each orbital, no matter what its size, can have a maximum of two electrons.




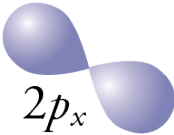



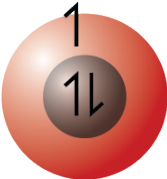
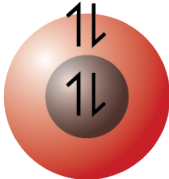
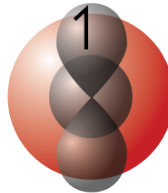
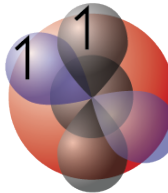
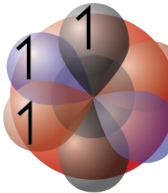
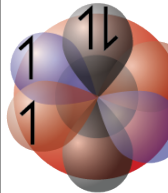
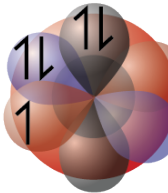
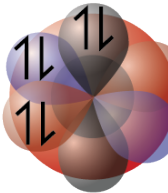
Orbital Diagrams



Drawing Orbital Diagrams

- For each sublevel with at least one electron, draw one line for each s sublevel, three lines for each p sublevel, five lines for each d sublevel, and seven lines for each f sublevel.
- Label each sublevel.
- Move up the page to indicate the order in which the orbitals are filled. For the first 18 elements, the order of filling is $1s$ $2s$ $2p$ $3s$ $3p$. A more complete order of filling will be described soon.
- For orbitals containing two electrons, draw one arrow up and one arrow down to indicate the electrons' opposite spin.
- When adding electrons to orbitals of the same energy, follow Hund's Rule.

Second Period Electron Configurations

1 H $1s^1$ 						2 He $1s^2$ 	
3 Li $1s^2 2s^1$ 	4 Be $1s^2 2s^2$ 	5 B $1s^2 2s^2 2p^1$ 	6 C $1s^2 2s^2 2p^2$ 	7 N $1s^2 2s^2 2p^3$ 	8 O $1s^2 2s^2 2p^4$ 	9 F $1s^2 2s^2 2p^5$ 	10 Ne $1s^2 2s^2 2p^6$ 

Electron Configurations

- The information in orbital diagrams is often described in a shorthand notation called an ***electron configuration***.

Represents the principal energy level

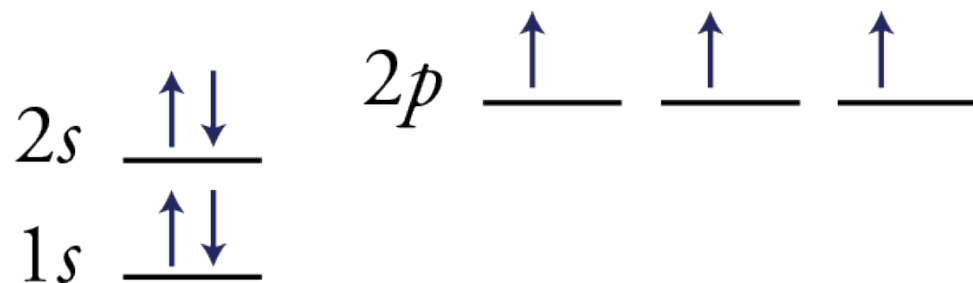
Shows the number of electrons in the orbital



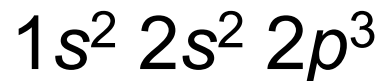
Indicates the shape of the orbital

Ways to Describe Electrons in Atoms

- The following is an orbital diagram for a nitrogen atom.



- The following is the electron configuration for nitrogen.

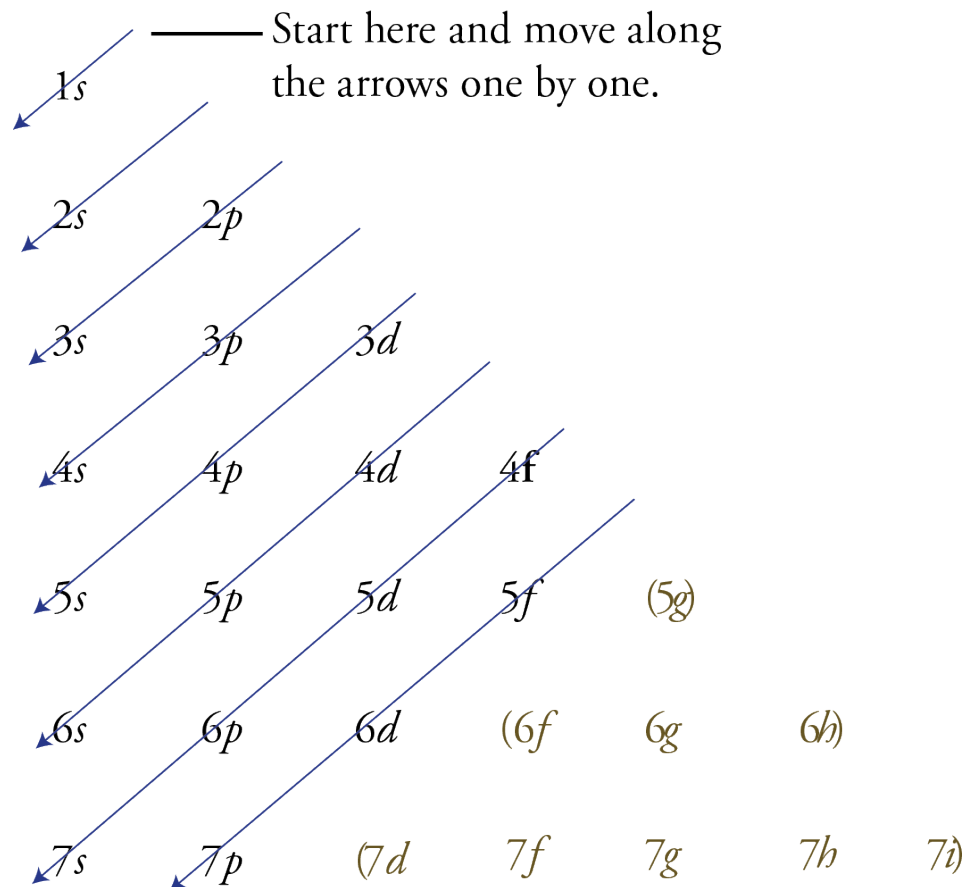


Writing Electron Configurations

The background of the slide features a sunset over a body of water. The sky is a gradient of blue and orange, with a bright sun partially obscured by clouds. In the foreground, the water reflects the colors of the sky. Scattered throughout the scene are numerous molecular models, each consisting of a central grey sphere (representing a nucleus) and several red spheres (representing electrons) orbiting it. The models are of various sizes and orientations, creating a sense of depth and movement.

- Determine the number of electrons in the atom from its atomic number.
- Add electrons to the sublevels in the correct order of filling.
- Add a maximum of two electrons to each *s* sublevel, 6 to each *p* sublevel, 10 to each *d* sublevel, and 14 to each *f* sublevel.

Order of Orbital Filling



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

Order of Filling from the Periodic Table

<i>s</i> block		<i>d</i> block										<i>p</i> block								
1	2											13	14	15	16	17	18			
1A	2A											3A	4A	5A	6A	7A	8A			
2s	3 Li	4 Be											5 B	6	7	8	9	10 Ne		
3s	11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A		
4s	19	20	3d	21 Sc	22	23	24	25	26	27	28	29	30 Zn	4p	31	32	33	34	35	36 Ar
5s	37	38	4d	39 Y	40	41	42	43	44	45	46	47	48 Cd	5p	49	50	51	52	53	54
6s	55	56	5d	71	72	73	74	75	76	77	78	79	80	6p	81	82	83	84	85	86
7s	87 Fr	88 Ra	6d	103 Lr	104	105	106	107	108	109	110	111	112 Cn	7p	113 Nh	114	115	116	117	118 Og

1s
1
H

f block

4f	57 La	58	59	60	61	62	63	64	65	66	67	68	69	70 Yb
5f	89 Ac	90	91	92	93	94	95	96	97	98	99	100	101	102 No

Long Periodic Table

s block

1 2
1A 2A

3 2s	4
11 3s	12
19 4s	20
37 5s	38
55 6s	56
87 7s	88

f block

57 4f	58	59	60	61	62	63	64	65	66	67	68	69	70
89 5f	90	91	92	93	94	95	96	97	98	99	100	101	102

d block

3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	8 8B	9 8B	10 8B	11 1B	12 2B					
21 3d	22	23	24	25	26	27	28	29	30	31 4p	32	33	34	35	36
39 4d	40	41	42	43	44	45	46	47	48	49 5p	50	51	52	53	54
71 5d	72	73	74	75	76	77	78	79	80	81 6p	82	83	84	85	86
103 6d	104	105	106	107	108	109	110	111	112	113 7p	114	115	116	117	118

1 1s

p block

13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
----------	----------	----------	----------	----------	----------

Exercise 4.2 and 11.1

Write the complete electron configuration and draw an orbital diagram for antimony, Sb.

Abbreviated Electron Configurations



- The highest energy electrons are most important for chemical bonding.
- The noble gas configurations of electrons are especially stable and, therefore, not important for chemical bonding.
- We often describe electron configurations to reflect this representing the noble gas electrons with a noble gas symbol in brackets.
- For example, for sodium
 $1s^2 2s^2 2p^6 3s^1$ goes to $[\text{Ne}] 3s^1$

Abbreviated Electron Configuration Steps for Zinc

Step 1 Find the symbol for the element (zinc).

Step 2 Write the symbol in brackets for the nearest, smaller noble gas.

Step 3 Write the outer electron configuration for the remaining electrons.

[Ar] 4s² 3d¹⁰

	1	2											13	14	15	16	17	18	
	1A	2A											3A	4A	5A	6A	7A	8A	
																			He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne	
3	11 Na	12 Mg	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
4	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	
5	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	
6	55 Cs	56 Ba	71 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	
7	87 Fr	88 Ra	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Uuu	112 Uub		114 Uuq		116 Uuh			
			6	57 La	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		
			7	89 Ac	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		

Exercise 4.3 and 11.2



Write abbreviated electron configurations for
(a) rubidium, Rb, (b) bismuth, Bi.

Common Mistakes



- Complete electron configurations – miscounting electrons (Use the periodic table to determine order of filling.)
- Orbital diagrams – forgetting to leave electrons unpaired with the same spin when adding electrons to the p , d , or f sublevels (Hund's Rule)
- Abbreviated electron configurations - forgetting to put $4f^{14}$ after [Xe]

Electron Configuration Tutorials

The background of the slide features a sunset over a body of water. The sky is a gradient of blue and orange, with a bright sun partially obscured by clouds. In the foreground, there are silhouettes of mountains or hills. Scattered across the sky and water are numerous molecular models, each consisting of a central grey sphere (likely representing a carbon atom) bonded to one or two red spheres (likely representing oxygen atoms). The models are shown in various orientations and sizes, creating a sense of depth and movement.

- Complete electron configurations.

https://preparatorychemistry.com/Comp_Electron_Config_Canvas.html

- Abbreviated electron configurations

https://preparatorychemistry.com/Abb_Electron_Config_Canvas.html