Chem 1045General Chemistry by Ebbing and Gammon, 8th EditionGeorge W.J. Kenney, JrLast Update: 06-Apr-2009

Chapter 8 Electron Configuration and Periodicity

These Notes are to <u>SUPPLIMENT</u> the Text, They do NOT Replace reading the Text Material. Additional material that is in the Text will be on your tests! To get the most information, <u>READ THE</u> <u>CHAPTER</u> prior to the Lecture, bring in these lecture notes and make comments on these notes. These notes alone are NOT enough to pass any test!

The author is providing these notes as an addition to the students reading the text book and listening to the lecture. Although the author tries to keep errors to a minimum, the student is responsible for correcting any errors in these notes.

8.1 Electron Spin and Pauli Exclusion Principle: A beam of hydrogen atoms is split into 2 by a magnetic field.

Atoms are Magnetic: Stern and Gerlach observed the splitting of a beam of hydrogen atoms by a magnetic field. This shows the atoms are magnetic – the electrons of different atoms spin in opposite directions [M = -1/2 and $+\frac{1}{2}$]



Electron Configuration of an atom is a particular distribution of electrons among available subshells

Orbital Diagrams show how the orbital's of a subshell are occupied by electrons:

$$\uparrow \downarrow \qquad \uparrow \downarrow \qquad \uparrow 0 \ 0 \qquad \qquad \uparrow = m_s \ [\ spin \] = + \frac{1}{2} \quad \downarrow = m_s = -\frac{1}{2}$$

$$\mathbf{1s} \qquad \mathbf{2s} \qquad \mathbf{2p}$$

Paui exclusion principle: no two electrons in an atom have the same 4 Quantum Numbers

Subshell	#Orbitals	Max # of Electrons
s (1=0)	1	2
p (1=1)	3	6
d (l = 2)	5	10
f $(1 = 3)$	7	14

Example 8.1: Which orbital diagrams are possible

	1s	2s		2p				
	↑↓	$\uparrow\downarrow$		↑				Possible
	↑↓	$\uparrow \downarrow \uparrow$						Impossible
	1↓	1		↑ ↑				Impossible
	1 s ³	$2 s^{1}$						Impossible
	1 s ²	2 s ¹	2 p ⁷					Impossible
	$1 s^{2}$	2 s ²	$2 p^{6}$	3 s ²	3 p ⁶	3 d ⁸	4 s ²	Possible
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Which orbital diagrams are possible

	1s	C	2s	-	2p		
a,	↑		↑		_		
b.	↑		↑		$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$
c.	↑↓		$\uparrow\downarrow$		$\uparrow \uparrow$	$\uparrow\downarrow$	↑↓
d.	$1s^2$	$2s^2$	$2p^4$				
e.	$1s^2$	$2s^4$	$2p^2$				
f.	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^{10}$	30	l^{10}





8.2 Build up Principle of the Periodic Table

Ground State: Configuration of the lowest energy level **Excited State:** All other configurations

AufBau Build Up Principle: scheme used to reproduce the electron configuration of the ground state by successively filling subshells with electrons in a specific order. This order represents an increase in energy for different subshells. Different orbitals of a subshell all have the same energy [each of the 3 basic electrons of a p subshell have the same energy].



NOTE CHANGE OF FILL PATTERN FROM $3p \rightarrow 4s$

Filling a subshell gives a stable configuration

Table 8.2: Do Z = 1 to 36 of Z & Configuration, fill all subshells. Note: filling a p subshell is a stable Atomic Number = z = # of protons = # of electrons configuration.



Orbital Energies of Scandium, Z=21. Note order 4s > 3d > 3d (??)

Using the Noble Gas Core abbreviations [inner shell configuration is a noble gas]

	Z=2	He	$1s^2$								
Fill th	e 2s sul	oshell									
	Z=3	Lithium	$1s^2$	$2s^1$					[He]	$2s^1$	
	Z=4	Beryllium	$1s^2$	$2s^2$					[He]	$2s^2$	
Start f	filling t	he 2p subshell									
	Z=5	Boron	$1s^2$	$2s^2$	$2p^1$				[He]	$2s^2$	$3p^1$
	Z=6	Carbon	$1s^2$	$2s^2$	$2p^2$				[He]	$2s^2$	$3p^2$
	•••		2	2	6					2	6
	Z=10	Neon	$1s^2$	$2s^2$	2p°				[He]	$2s^2$	3p°
Fill th	e 3s sul	oshell	2	2	<i>,</i>						
	Z=11	Sodium	$1s^2$	$2s^2$	2p ⁶	$3s^1$			[Ne]	$3s^1$	
	Z=12	Magnesium	$1s^2$	$2s^2$	$2p^6$	$3s^2$			[Ne]	$3s^2$	
Fill th	e 3p su	bshell									
	Z=13	Aluminum	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^1$		[Ne]	$3s^2$	$3p^1$
	 Z=18	Argon	$1s^2$	$2s^2$	2p ⁶	$3s^2$	3p ⁶		[Ne]	$3s^2$	3p ⁶
Noble	Gases -	- Very Unreact	tive								
	Z=2	Не	$1s^2$								
	Z=10	Neon	$1s^2$	$2s^2$	$2p^6$						
	Z=18	Argon	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^6$				
	Z=36	Krypton	$1s^2$	$2s^2$	$2p^6$	$3s^2$	3p ⁶	$3d^{10}$	$4s^2$	4p ⁶	
Group	o IIA, A	lkaline Earth	Metals	– Mode	erately 1	reactive	, loose 2	2 electro	ons		
	Z=4	Beryllium	$1s^2$	$2s^2$						[He]	$2s^2$
	Z=12	Magnesium	$1s^2$	$2s^2$	$2p^6$	$3s^2$				[Ne]	$3s^2$
	Z=20	Calcium	$1s^2$	$2s^2$	$2p^6$	$3s^2$	3p ⁶	$3d^{10}$	$4s^2$	[Ar]	$4s^2$

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Group IIIA,

Z=5	Boron	$1s^2$	$2s^2$	$2p^1$						[He] $2s^2$	$3p^1$
Z=13	Aluminum	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^1$				$[Ne] 3s^2$	$3p^1$
Z=31	Galilium	$1s^2$	$2s^2$	$2p^6$	$3s^2$	3p ⁶	$3d^{10}$	$4s^2$	$4p^1$	$[Ar] 4s^2$	$4p^1$

Boron and Aluminum have the noble gas cores plus 3 electrons Gallium has an additional filled 3d subshell. **Pseudo-Noble-Gas core** is a noble gas core with $(n - 1)d^{10}$ electrons

Valence Electrons: Electrons in an atom outside the Noble-Gas or Pseudo-Noble-Gas core.

Main	n-Gro s subs	up Ele	ments ls											Main p	-Grou subsh	p Elei ell fil	ments ls	È.
	IA				3	H Sy V	tomic ymbol alence	numbe -shell	r config	uratio	n							
1	H 1 <i>s</i> ³	IIA											ША	IVA	VA	VIA	VIIA	He Is ²
2	3 Li 2x ¹	4 Be 2s ²	_	Transition Metals d subshell fills									5 B 2s ² 2p ¹	6 C 2s ² 2p ²	7 N 2s ² 2p ³	8 0 2s ² 2p ⁴	9 F 2s ² 2p ³	10 Ne 2s ³ 2p ⁶
3	11 Na 33 ¹	12 Mg 3x ²	шв	IIB IVB VB VIB VIIB - IB IIB							ПВ	13 Al 3s ² 3p ¹	14 Si 3s ² 3p ²	13 P 3s ² 3p ³	16 S 3s ² 3p ⁴	17 Cl 3s ² 3p ³	18 Ar 3s ² 3p ⁶	
Period 4	19 K 45 ¹	20 Ca 4x ²	21 Sc 3d ¹ 4x ²	22 Ti 3d ² 4s ²	23 V 3d ⁹ 4s ²	24 Cr 3d ⁵ 4s ¹	25 Mn 3d ⁵ 4s ²	26 Fe 3d ⁶ 4s ²	27 Co 3d ⁷ 4x ²	28 NI 3d ⁸ 4s ²	29 Cu 3d ¹⁰ 4x ¹	30 Zn 3d ¹⁰ 4x ²	31 Ga 4x ² 4p ¹	32 Ge 4s ² 4p ²	33 As 4s ² 4p ³	34 Se 4x ² 4p ⁴	35 Br 4x ² 4p ³	36 Kr 4x ² 4p ⁹
5	37 Rb 5s ¹	38 Sr 58 ²	39 Y 4d ¹ 5x ²	$40 \\ Zr \\ 4d^{2}5s^{2}$	$41 \\ \mathbf{Nb} \\ 4d^45s^4$	42 Mo 4d ⁵ 5s ¹	43 Tc 4d ³ 5s ²	44 Ru 4d ⁷ 5x ¹	45 Rh 4d ⁴ 5s ¹	46 Pd 4d ¹⁰	47 Ag 4d ¹⁰ 5x ¹	48 Cd 4d ¹⁰ 5s ²	49 In 5 <i>s</i> ² 5 <i>p</i> ³	50 Sn 5s ² 5p ²	51 Sb 5s ² 5p ³	52 Te 5s ² 5p ⁴	53 1 5s ² 5p ³	54 Xe 5x ² 5p ⁴
6	55 Cs 6x ¹	56 Ba 63 ²	57 La* 5d ¹ 6s ²	72 Hf 5d ² 6s ²	73 Ta 5d ³ 6s ²	74 W 5d ⁴ 6s ²	75 Re 5d ⁵ 6s ²	76 Os 5d*6x ²	77 Ir 5d ⁷ 6s ³	78 Pt 5d ⁹ 6s ¹	79 Au 5d ¹⁰ 6s ¹	80 Hg 5d ¹⁰ 6s ³	84 TI 6x ² 6p ¹	82 Pb 6x ² 6p ²	83 Bi 6s ² 6p ³	84 Po 6x ³ 6p ⁴	85 At 6s ² 6p ⁵	86 Rn 6s ² 6p
7	87 Fr 7s ¹	88 Ra 7s ²	89 Ac** 6d ¹ 7s ²	104 Rf 6d ² 7 <i>s</i> ²	105 Db 6d ³ 7s ²	106 Sg 6d ⁴ 7s ²	107 Bh 6d ³ 7s ²	108 Hs 6d ⁶ 7s ³	109 Mt 6d ⁷ 7s ²	110 Uun 6d ⁸ 7s ²	111 Uuu 6d*7.s ²	112 Uub 6d ¹⁰ 7s ²		114 Uuq 7 <i>s</i> ² 7 <i>p</i> ²		110 Uuh 7 <i>s</i> ² 7 <i>p</i> ⁴		
					_				1	Inner- J	Trans subsh	ell fill	Metal: ls	5				
			*Lanth	anides	58 Ce 4f ¹ 5d ¹ 6s ²	59 Pr 4f ³ 6s ²	60 Nd 4f ⁴ 6s ²	61 Pm 4f ³ 6x ²	62 Sm 4f ⁴ 6s ²	63 Eu 4f ⁷ 6s ²	64 Gd 4/ ² 5d ⁴ 6s ²	65 Tb 4f ⁹ 6s ²	66 Dy 4f ¹⁸ 63 ²	67 Ho 4f ¹¹ 6s ²	68 Er 4f ¹² 6s ²	59 Tm 4f ¹³ 6s ²	70 Yb 4f ¹⁴ 6s ²	71 Lu 4/145/76
			**Act	tinides	90 Th 6d ² 7s ²	91 Pa 5f ² 6d ¹ 7x ²	92 U 5f ⁵ 6d ¹ 7s ²	93 Np 5f*6d*7s ²	94 Pu Sf ⁴ 73 ²	95 Am 5f ⁷ 7s ²	96 Cm 5/26d*7s ²	97 Bk 5f*7s ²	98 Cf 5f ¹⁰ 7s ²	99 Es 5f ¹¹ 7s ²	100 Fm Sf ¹² 7s ²	101 Md 5f ¹² 7s ¹	102 No 5f ¹⁴ 7s ²	103 Lr 5/146/17

Periodic Table with valence-shell electrons. Note groups have similar electron configuration [and properties] **Going Across a Period:**

1A v 1	IIA	$\operatorname{IIIA}_{\mathbf{V}_{2}}$	IVA	VA	VIA	VIIA \mathbf{V}_{2}^{2} 5	VIIIA
XS	Xs ⁻	Xs ⁻ p ⁻	Xs ⁻ p ⁻	Xs ⁻ p ⁻	Xs ⁻ p	Xs ⁻ p ⁻	Xs ⁻ p ⁻

Transitio	Fransition Metals, d subshell fills											
IIIB	IVB	VB	VI	VIIB	VIIIB	VIIIB	VIIIB	I B	IIB			
Sc	Ti	Y	Cr	Mn	Fe	Co	Ni	Cu	Zn			
Z=21	Z=22	Z=23	Z=24*	Z=25	Z=26	Z=27	Z=28	Z=29*	Z=230			
$Xd^{1}4s^{2}$	Xd^24s^2	$Xd^{3}4s^{2}$	$Xd^{5}4s^{1}$	$Xd^{5}4s^{2}$	$Xd^{6}4s^{2}$	$Xd^{7}4s^{2}$	Xd^84s^2	$Xd^{10}4s^1$	$Xd^{10}4s^2$			
*	One electro	on is prome	ted from th	e As to the	1d subshell	for $7 - 14$	8, 20					

* One electron is promoted from the 4s to the 4d subshell for Z = 14 & 29

Exceptions to the Build up Principle

Cr	Z=24	$[Ar] 3d^4$	$4s^2$	\rightarrow	$3d^5$	$4s^1$
Cu	Z=29	$[Ar] 3d^9$	$4s^2$	\rightarrow	$3d^{10}$	$4s^1$

X-Ray is generated when an electron beam that falls on a metal target.

With sufficient energy, the electron knocks an electron from an **inner shell** giving a metal ion with a missing inner orbital. An electron from a higher orbital drops down and an X-Ray photon is emitted.



Note: The Principal Quantum Number of the Valence Shell Electron must equal the Period!

Exam	ple: 8.	2 Wha	t is the	ground	state co	nfigura	ation for	Ga Z	= 31
	_		1s	2s 2p	3s 3p	4s	3d	4p	From the AufBau Build Up Principle
	Then	fill		-	-	$4s^2$	$3d^{10}$	$4p^1$	
	Valen	ce Shel	l is			$4s^2$		$4p^1$	
	ns ^a	np ^b	n is th # of V	ie Princi Valence (ple Qua Shell E	antum I lectron	Number s = a + b	= 3.	So the Group Number = 3
Exam	ple: 8.3	8 What	are the	outer sl	nell con	figurat	tion of T	e, Z =	52
	From	the Per	iodic Ta	able, Te	is in Pe	eriod 5,	Group '	VIA:	n = 5, # electrons = 6
		$5s^2$	$5p^4$				-		
Exerc	cise 8.3	What i	s the va	lence sh	ell con	figurati	ion of ar	senic	(As, Z = 33)?

Arsenic is a main group element in Period 4, Group VA, of the periodic table. The five outer electrons should occupy the 4s and 4p subshells $4s^2 4p^3$.

Concept Check 8.2 Two adjacent elements in Period 3. One has only s electrons in it's valence shell, the other has only 1 p electron. Mg & Al

<u>8.4 Hunds Rule:</u> The lowest energy arrangements of electrons in a subshell is putting the electrons into separate orbital's of the subshell with the same spin before paring them.

15	lp	2p	15	lp		2p		
$\uparrow\downarrow$	$\uparrow\downarrow$		$\uparrow\downarrow$	$\uparrow\downarrow$	1	1	↑	
$\uparrow\downarrow$	$\uparrow\downarrow$	1	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	1	↑	
$\uparrow\downarrow$	$\uparrow\downarrow$	\uparrow \uparrow	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	↑	
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Atom	Z	Configuration	1 <i>s</i>	2 s	2р
Hydrogen	1	$1s^{1}$	\bigcirc	0	000
Helium	2	$1s^2$	(1)	\bigcirc	000
Lithium	3	$1s^2 2s^1$	(1)	\bigcirc	000
Beryllium	4	$1s^2 2s^2$	(1)	1	000
Boron	5	$1s^2 2s^2 2p^1$	(1)	(1)	$\bigcirc \bigcirc \bigcirc \bigcirc \bigcirc$
Carbon	6	$1s^2 2s^2 2p^2$	(1)	1	OOO
Nitrogen	7	$1s^2 2s^2 2p^3$	(1)	1	DDD
Oxygen	8	$1s^2 2s^2 2p^4$	(1)	(1)	
Fluorine	9	$1s^2 2s^2 2p^5$	1	(1)	
Neon	10	$1s^2 2s^2 2p^6$	(1)	(1)	

Table 8.2 Orbital Buildup Diagram

Example 8.4	Iron is $1s^2$ $\uparrow\downarrow$	$1s^{2} 2s^{2}$ $2s^{2}$ $\uparrow\downarrow$	$\begin{array}{c} 2p^6 \ 3s \\ 2p' \\ \uparrow \downarrow \ \uparrow \downarrow \end{array}$	$^{2}_{6}3p^{6}$ 3c	$4^{6} 4s^{2}$. $3s^{2}$ $\uparrow\downarrow$	Draw t 3_1 $\uparrow\downarrow\uparrow\uparrow$	he orb p ⁶ ↓ ↑↓	itals ↑↓	$3d^6$ \uparrow \uparrow	↑ ↑	$4s^2$ $\uparrow\downarrow$		
Build up for	· Sodiun	n, atomi	c numl	oer 11:									
- 1s	2s		2p			3s							
		-1	0	+1									
$\uparrow\downarrow$	$\uparrow\downarrow$	↑↓	î↓	$\uparrow\downarrow$		Î							
Build up for Chlorine, atomic number 17:													
1s	2s		2p			3s		3p					
		-1	0 +	1			-1	0	+1				
$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$		$\uparrow\downarrow$	$\uparrow\downarrow$	$\uparrow\downarrow$	1				

Paramagnetic Substance: a substance that is weakly attracted by a magnetic field and this attraction is generally the result of unpaired electrons.

Diamagnetic Substance: a substance that is not attracted by a magnetic field or is very slightly repelled by such a field. The substance has only paired electrons.

8.5 Mendellev's Predictions

This section is not normally covered during lectures.

8.6 Some Periodic Properties

<u>The Periodic Law</u> states the when the elements are arranged by atomic number, their physical and chemical properties vary periodically.

Atomic Radius

- 1
- 2

Effective Nuclear Charge

Ionization Energy

First Ionization Potential:

Second Ionization Potential:

Electron Affinity

Electron affinity is the energy change for the process of adding an electron to a neutral atom in the gaseous state to form a negative ion.

8.7 Periodicity in the Main Group Elements

Practice Questions:

Review Questions: All Example Problems in the chapter

Concept Questions: 7.19, 7.23, 7.27

 Practice Problems:
 7.33, 7.35, 7.41

 7.43, 7.45, 7.51
 7.57, 7.59, 7.61, 7.63

Some examples of discrepancies in the electron fill sequence: [DRAFT 3-27-09]

Boron	5	1s ↑↓ ↑↓	2s ↑↓ ↑	← 2px ↑ ↑	2p 2py ↑	→ 2pz					Hybi	ridize	s to th	nis sp²	e.g.	BF ₃
Carbon	6	1s ↑↓ ↑↓	2s ↑↓ ↑	← 2px ↑↓ ↑	2p 2py ↑	→ 2pz					Hybi	ridize	s to th	uis sp ³	e.g.	CH4
Aluminum	13	1s ↑↓ ↑↓	2s ↑↓ ↑↓	← 2px ↑↓ ↑↓	2p 2py ↑↓ ↑↓	$\begin{array}{c} \boldsymbol{\rightarrow} \\ \mathbf{2pz} \\ \uparrow \downarrow \\ \uparrow \downarrow \end{array}$	3s ↑↓ ↑	← 3px ↑ ↑	3p 3py ↑	→ 3pz	Hybi	ridize	s to th	nis sp ³	e.g.	AICl ₃
Silicon	14	$\stackrel{\uparrow\downarrow}{\uparrow\downarrow}$	$\stackrel{\uparrow\downarrow}{\uparrow\downarrow}$	← ↑↓ ↑↓	2p ↑↓ ↑↓	$\begin{array}{c} \boldsymbol{\rightarrow} \\ \uparrow \downarrow \\ \uparrow \downarrow \end{array}$	$\uparrow \downarrow \\ \uparrow$	← ↑	3 p ↑ ↑	→	Hybi	ridize	s to th	uis sp ³	e.g.	SiH4
Chromium Goes to this:	24	$1s \\ \uparrow \downarrow \\ \uparrow \downarrow$	2s $\uparrow\downarrow$ $\uparrow\downarrow$	← 2px ↑↓ ↑↓	2p 2py ↑↓ ↑↓	$\begin{array}{c} \boldsymbol{\rightarrow} \\ \mathbf{2pz} \\ \uparrow \downarrow \\ \uparrow \downarrow \end{array}$	3s ↑↓ ↑↓	← 3px ↑↓ ↑↓	3p 3py ↑↓ ↑↓	→ 3pz ↑↓ ↑↓	4s ↑↓ ↑	← 3d1 ↑	3d2 ↑ ↑	3d 3d3 ↑ ↑	3d4 ↑ ↑	→ 3d5
Copper Goes to this:	29	1s ↑↓ ↑↓	2s $\uparrow\downarrow$ $\uparrow\downarrow$	← 2px ↑↓ ↑↓	2p 2py ↑↓ ↑↓	$\begin{array}{c} \boldsymbol{\rightarrow} \\ \mathbf{2pz} \\ \uparrow \downarrow \\ \uparrow \downarrow \end{array}$	3s ↑↓ ↑↓	← 3px ↑↓ ↑↓	3p 3py ↑↓ ↑↓	→ 3pz ↑↓ ↑↓	4s ↑↓ ↑	← 3d1 ↑↓ ↑↓	3d2 ↑↓ ↑↓	3d 3d3 ↑↓ ↑↓	3d4 ↑↓ ↑↓	→ 3d5 ↑ ↑↓
Silver Goes to this:	47	← 3d1 ↑↓ ↑↓	3d2 ↑↓ ↑↓	3 2 3d ↑↓ ↑↓	d 3 30 ↑↓ ↑↓	d4 3 ↑↓ ↑↓	→ d5 ↑↓ ↑↓	← 4px { ↑↓ ↑↓	4p 4py ↑↓ ↑↓	→ 4pz ↑↓ ↑↓	5s ↑↓ ↑	← 4d1 ↑↓ ↑↓	4d2 ↑↓ ↑↓	4d 4d3 ↑↓ ↑↓	4d4 ↑↓ ↑↓	→ 4d5 ↑ ↓