

# CHEM 120 Spring 2017

## Introduction to Inorganic Chemistry

**Instructor** Dr. Upali Siriwardane (Ph.D. Ohio State)

E-mail: upali@latech.edu

**Office:** 311 Carson Taylor Hall ; Phone: 318-257-4941;

**Office Hours:** MWF 8:00-9:00 and 11:00-12:00;  
TR 10:00-12:00

Contact me through phone or e-mail if you have questions

## Online Tests on Following days

March 24, 2017: Test 1 (Chapters 1-3)

April 7, 2017 : Test 2 (Chapters 4-5)

April 28, 2017: Test 3 (Chapters 6,7 &8)

May 12, 2017 : Test 4 (Chapters 9, 10 &11)

May 15, 2017: Make Up Exam: Chapters 1-11)

.

## **Table of Contents**

[3.1 Internal Structure of an Atom](#)

[3.2 Atomic Number and Mass Number](#)

[3.3 Isotopes and Atomic Masses](#)

[3.4 The Periodic Law and the Periodic Table](#)

[3.5 Metals and Nonmetals](#)

[3.6 Electron Arrangements Within Atoms](#)

[3.7 Electron Configurations and Orbital Diagrams](#)

[3.8 The Electronic Basis for the Periodic Law and the Periodic Table](#)

[3.9 Classification of the Elements](#)

# Internal Structure of an Atom

## Subatomic Particle

- A very small particle that is a building block for atoms.

# Internal Structure of an Atom

## Three Types of Subatomic Particles

- The atom contains:
  - *Electrons* – found outside the nucleus; possesses a negative electrical charge; smallest mass.
  - *Protons* – found in the nucleus; positive charge equal in magnitude to the electron's negative charge.
  - *Neutrons* – found in the nucleus; no charge; virtually same mass as a proton.

# Internal Structure of an Atom

## Charge and Mass Characteristics

**Table 3.1** Charge and Mass Characteristics of Electrons, Protons, and Neutrons

	Electron	Proton	Neutron
Charge	-1	+1	0
Actual mass (g)	$9.109 \times 10^{-28}$	$1.673 \times 10^{-24}$	$1.675 \times 10^{-24}$
Relative mass (based on the electron being 1 unit)	1	1837	1839

# Internal Structure of an Atom

- The nucleus is:
  - Small compared with the overall size of the atom.
  - Extremely dense; accounts for almost all of the atom's mass.
  - Positively charged center of an atom.

# Internal Structure of an Atom

## Charge Neutrality of an Atom

- An atom as a whole is electrically neutral (no net electrical charge).

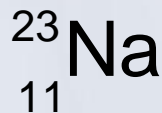
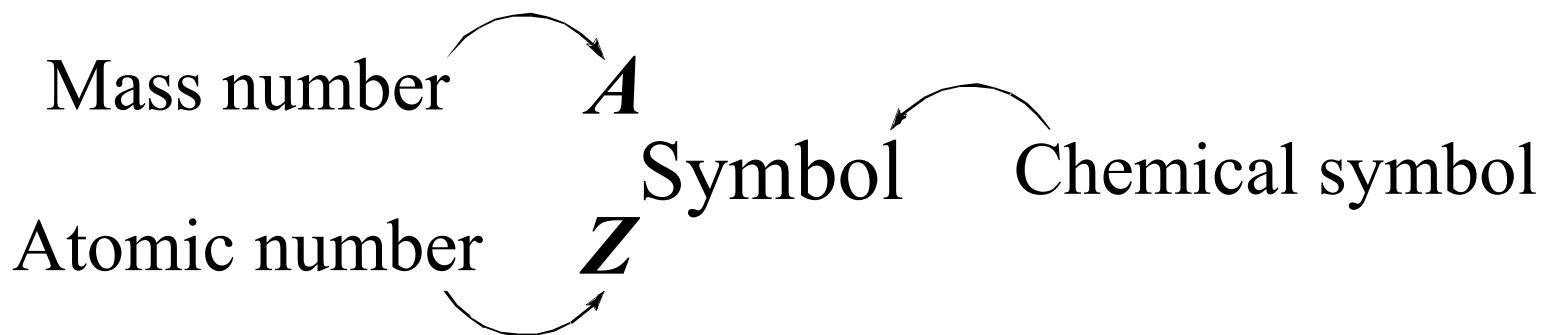
# of Protons = # of Electrons

# Atomic Number and Mass Number

- Atomic Number ( $Z$ ) – # of protons in the nucleus of an atom.
- Mass Number ( $A$ ) – sum of the # of protons and the # of neutrons in the nucleus of an atom.

# Atomic Number and Mass Number

## Complete Chemical Symbol Notation



# Atomic Number and Mass Number

## Element

- A pure substance in which all atoms present have the same atomic number.
- All atoms with the same atomic number have the same chemical properties and are atoms of the same element.

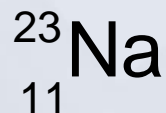
# Isotopes and Atomic Masses

## Isotopes

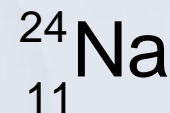
- Atoms of an element that have the same number of protons and the same number of electrons but different numbers of neutrons.
- Show almost identical chemical properties; chemistry of atom is due to its electrons.
- Physical properties are often slightly different because they have different masses.
- In nature most elements contain mixtures of isotopes.

# Isotopes and Atomic Masses

## Two Isotopes of Sodium



- Number of Protons = 11
- Mass number = 23
- Number of Neutrons = 12



- Number of Protons = 11
- Mass number = 24
- Number of Neutrons = 13

# Isotopes and Atomic Masses



## Exercise

A certain isotope X contains **23** protons and **28** neutrons.

- What is the **mass number** of this isotope?
- Identify the **element**.

# Isotopes and Atomic Masses



## Exercise

A certain isotope X contains **23** protons and **28** neutrons.

- What is the **mass number** of this isotope?

**51**

- Identify the **element**.

**Vanadium**

# Isotopes and Atomic Masses

## Atomic Masses

- Elements occur in nature as mixtures of isotopes.
- Carbon =  
98.89%  $^{12}\text{C}$   
1.11%  $^{13}\text{C}$   
 ~~$\leq 0.01\%$   $^{14}\text{C}$~~
- Calculated average mass for the isotopes of an element expressed on a scale where  $^{12}_6\text{C}$  serves as the reference point.

# Isotopes and Atomic Masses

## Average Atomic Mass for Carbon

98.89% of 12 amu + 1.11% of 13.0034 amu =

$(0.9889)(12 \text{ amu}) + (0.0111)(13.0034 \text{ amu}) =$

12.01 amu

# Isotopes and Atomic Masses



## Exercise

An element consists of 62.60% of an isotope with mass 186.956 amu and 37.40% of an isotope with mass 184.953 amu.

- Calculate the **average atomic mass** and identify the **element**.

$$(62.60\% \text{ of } 186.956 \text{ amu} + 37.40\% \text{ of } 184.953)/100$$

$$(0.6260)(186.956 \text{ amu}) + (0.0111)(184.953 \text{ amu}) \\ = 186.207 \text{ amu}$$

# Isotopes and Atomic Masses



## Exercise

An element consists of 62.60% of an isotope with mass 186.956 amu and 37.40% of an isotope with mass 184.953 amu.

- Calculate the **average atomic mass** and identify the **element**.

Average Atomic Mass = 186.207 amu

The element is rhenium (Re).

# The Periodic Law and the Periodic Table

- *Periodic Law* – When elements are arranged in order of increasing atomic number, elements with similar chemical properties occur at periodic (regularly recurring) intervals.
- *Periodic Table* – Tabular arrangement of the elements in order of increasing atomic number such that elements having similar chemical properties are positioned in vertical columns.

# The Periodic Law and the Periodic Table

## The Periodic Table

- *Periods* – horizontal rows of elements
- *Groups* – elements in the same vertical columns; have similar chemical properties

## Section 3.4

# The Periodic Law and the Periodic Table

## The Periodic Table

Period	1 Group IA												18 Group VIIIA																																	
	1 H 1.01	2 Group IIA											13 Group IIIA	14 Group IVA	15 Group VA	16 Group VIA	17 Group VIIA	2 He 4.00																												
1	1 H 1.01	2 Group IIA																																												
2	3 Li 6.94	4 Be 9.01																																												
3	11 Na 22.99	12 Mg 24.31	3 Group IIIB	4 Group IVB	5 Group VB	6 Group VIB	7 Group VIIB	8 Group VIII	9 Group VIII	10 Group VIII	11 Group IB	12 Group IIB	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95																												
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80																												
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29																												
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)																												
7	87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (263)	105 Db (262)	106 Sg (266)	107 Bh (267)	108 Hs (277)	109 Mt (276)	110 Ds (281)	111 Rg (280)	112 Cn (285)	113 Nh (284)	114 Fl (289)	115 Mc (288)	116 Lv (292)	117 Ts (293)	118 Og (294)																												
			<table><tr><td>58 Ce 140.12</td><td>59 Pr 140.91</td><td>60 Nd 144.24</td><td>61 Pm (145)</td><td>62 Sm 150.36</td><td>63 Eu 151.96</td><td>64 Gd 157.25</td><td>65 Tb 158.93</td><td>66 Dy 162.50</td><td>67 Ho 164.93</td><td>68 Er 167.26</td><td>69 Tm 168.93</td><td>70 Yb 173.04</td><td>71 Lu 174.97</td></tr><tr><td>90 Th (232)</td><td>91 Pa (231)</td><td>92 U (238)</td><td>93 Np (237)</td><td>94 Pu (244)</td><td>95 Am (243)</td><td>96 Cm (247)</td><td>97 Bk (247)</td><td>98 Cf (251)</td><td>99 Es (252)</td><td>100 Fm (257)</td><td>101 Md (258)</td><td>102 No (259)</td><td>103 Lr (262)</td></tr></table>																58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97	90 Th (232)	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)
58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97																																	
90 Th (232)	91 Pa (231)	92 U (238)	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)																																	

Atomic number  
Symbol  
Atomic mass

Nonmetals

Metals

# The Periodic Law and the Periodic Table

## Groups

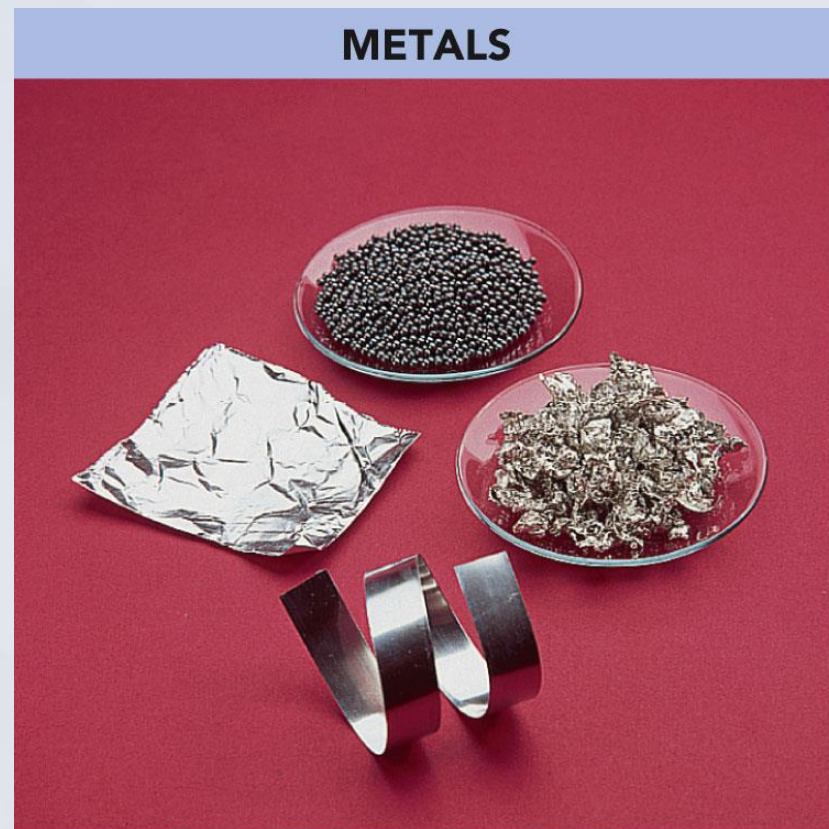
- Table of common charges formed when creating ionic compounds.

Group	Charge
Alkali Metals (1A)	1+
Alkaline Earth Metals (2A)	2+
Halogens (7A)	1-
Noble Gases (8A)	0

# Metals and Nonmetals

## Metal

- An element that has the characteristic properties of luster, thermal conductivity, electrical conductivity, and malleability.

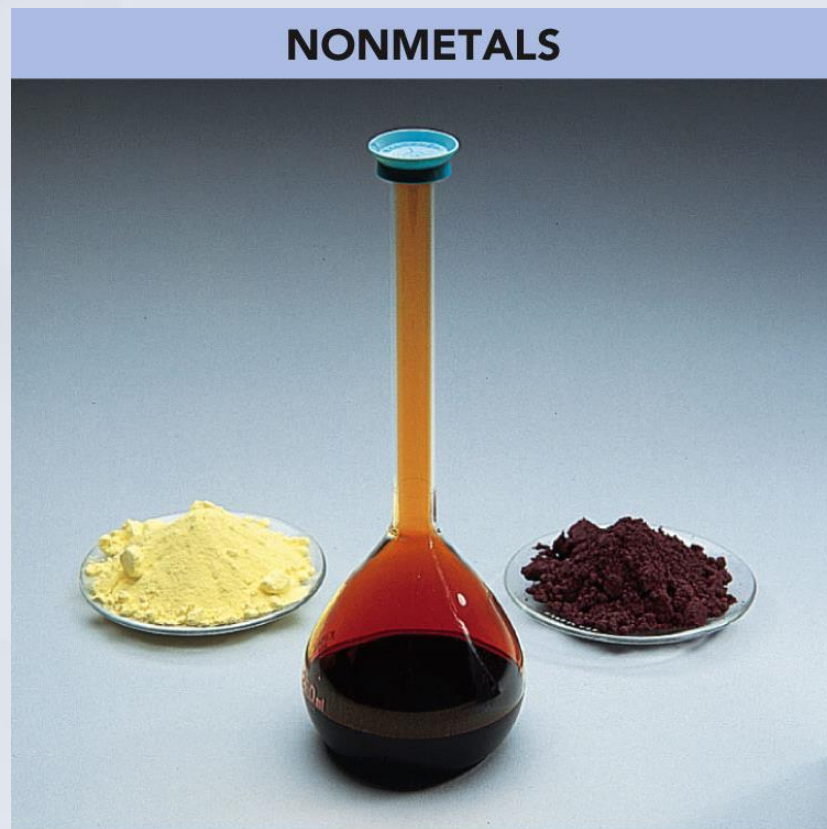


**a** Some familiar metals (clockwise, starting on left) are aluminum, lead, tin, and zinc.

# Metals and Nonmetals

## Nonmetal

- An element characterized by the *absence* of the properties of luster, thermal conductivity, electrical conductivity, and malleability.



**b** Some familiar nonmetals are sulfur (yellow), phosphorus (dark red), and bromine (reddish-brown liquid).

# Metals and Nonmetals

## Selected Physical Properties of Metals and Nonmetals

**Table 3.3** Selected Physical Properties of Metals and Nonmetals

Metals	Nonmetals
1. High electrical conductivity that decreases with increasing temperature	1. Poor electrical conductivity (except carbon in the form of graphite)
2. High thermal conductivity	2. Good heat insulators (except carbon in the form of diamond)
3. Metallic gray or silver luster*	3. No metallic luster
4. Almost all are solids <sup>†</sup>	4. Solids, liquids, or gases
5. Malleable (can be hammered into sheets)	5. Brittle in solid state
6. Ductile (can be drawn into wires)	6. Nonductile

\*Except copper and gold.

<sup>†</sup>Except mercury; cesium and gallium melt on a hot summer day (85°F) or when held in a person's hand.

## Metals and Nonmetals

### Dividing Line Between Metals and Nonmetals

		Group					VIIIA	
1		IIA	IIIA	IVA	VA	VIIA	2	
H							He	
		5	6	7	8	9	10	
		B	C	N	O	F	Ne	
		13	14	15	16	17	18	
		Al	Si	P	S	Cl	Ar	
		30	31	32	33	34	35	36
		Zn	Ga	Ge	As	Se	Br	Kr
		48	49	50	51	52	53	54
		Cd	In	Sn	Sb	Te	I	Xe
		80	81	82	83	84	85	86
		Hg	Tl	Pb	Bi	Po	At	Rn
		112	113	114	115	116	117	118
		Cn	—	—	—	—	—	—

Metal

Nonmetal

# Electron Arrangements Within Atoms

## Electron Shells

- A region of space about a nucleus that contains electrons that have approximately the same energy and that spend most of their time approximately the same distance from the nucleus.
- Electrons that occupy the first electron shell are closer to the nucleus and have a lower energy than electrons in the second electron shell.

# Electron Arrangements Within Atoms

## Electron Subshells

- A region of space within an electron shell that contains electrons that have the same energy.

Subshell	Number of Electrons
$s$	2
$p$	6
$d$	10
$f$	14

# Electron Arrangements Within Atoms

## Electron Orbitals

- A region of space within an electron subshell where an electron with a specific energy is most likely to be found.
- An electron orbital can accommodate a maximum of 2 electrons.

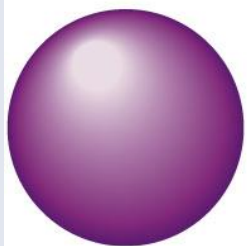
# Electron Arrangements Within Atoms

## Electron Orbitals

Subshell	Number of Orbitals
$s$	1
$p$	3
$d$	5
$f$	7

# Electron Arrangements Within Atoms

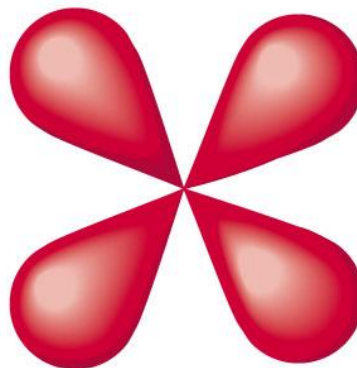
## Electron Orbitals



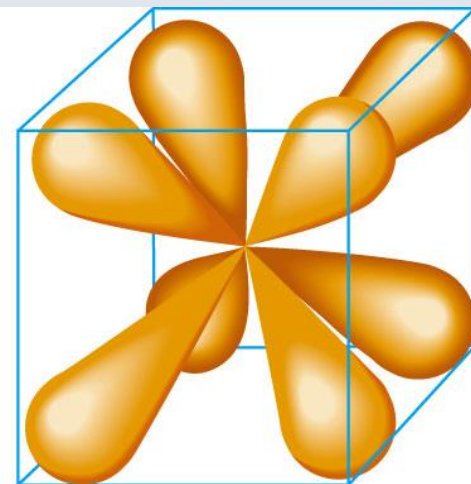
a s orbital



b p orbital



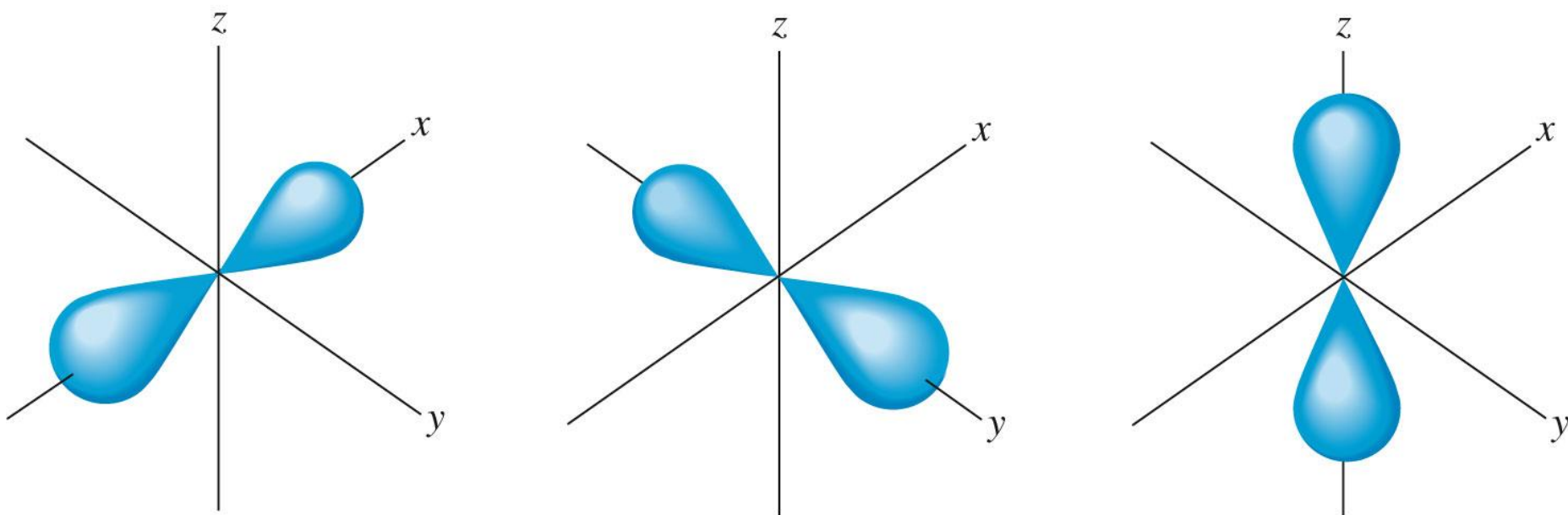
c d orbital



d f orbital

# Electron Arrangements Within Atoms

## Orbitals Within the Same Subshell Differ in Orientation



# Electron Arrangements Within Atoms

## Electron Spin

- As an electron “moves about” within an orbital, it spins on its own axis in either a clockwise or a counterclockwise direction.
- When two electrons are present in an orbital, they always have opposite spins.

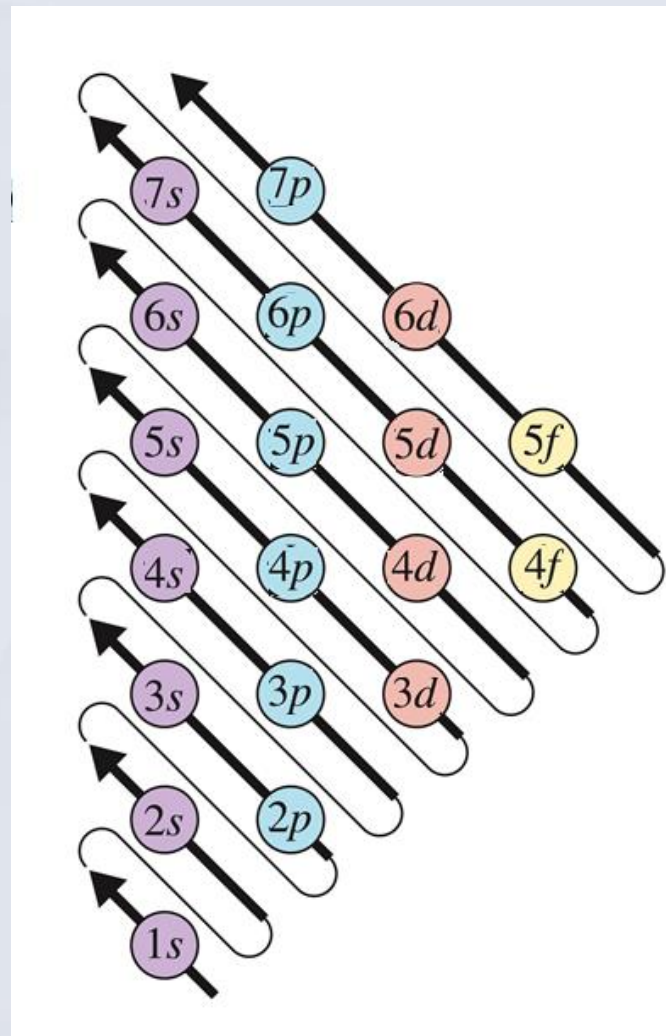
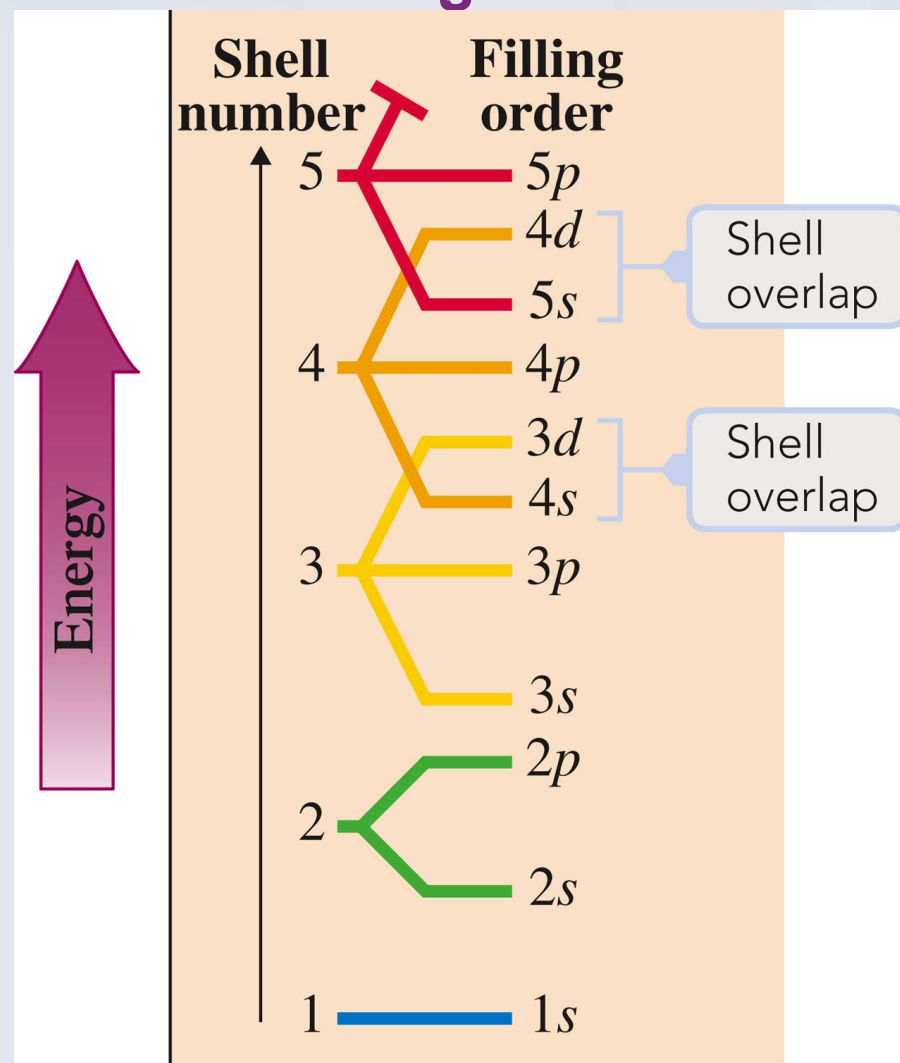
# Electron Configurations and Orbital Diagrams

## Rules for Assigning Electrons to Various Shells, Subshells, and Orbitals

1. Electron subshells are filled in order of increasing energy.
2. Electrons occupy the orbitals of a subshell such that each orbital acquires one electron before any orbital acquires a second electron. All electrons in such singly occupied orbitals must have the same spin.
3. No more than two electrons may exist in a given orbital – and then only if they have opposite spins.

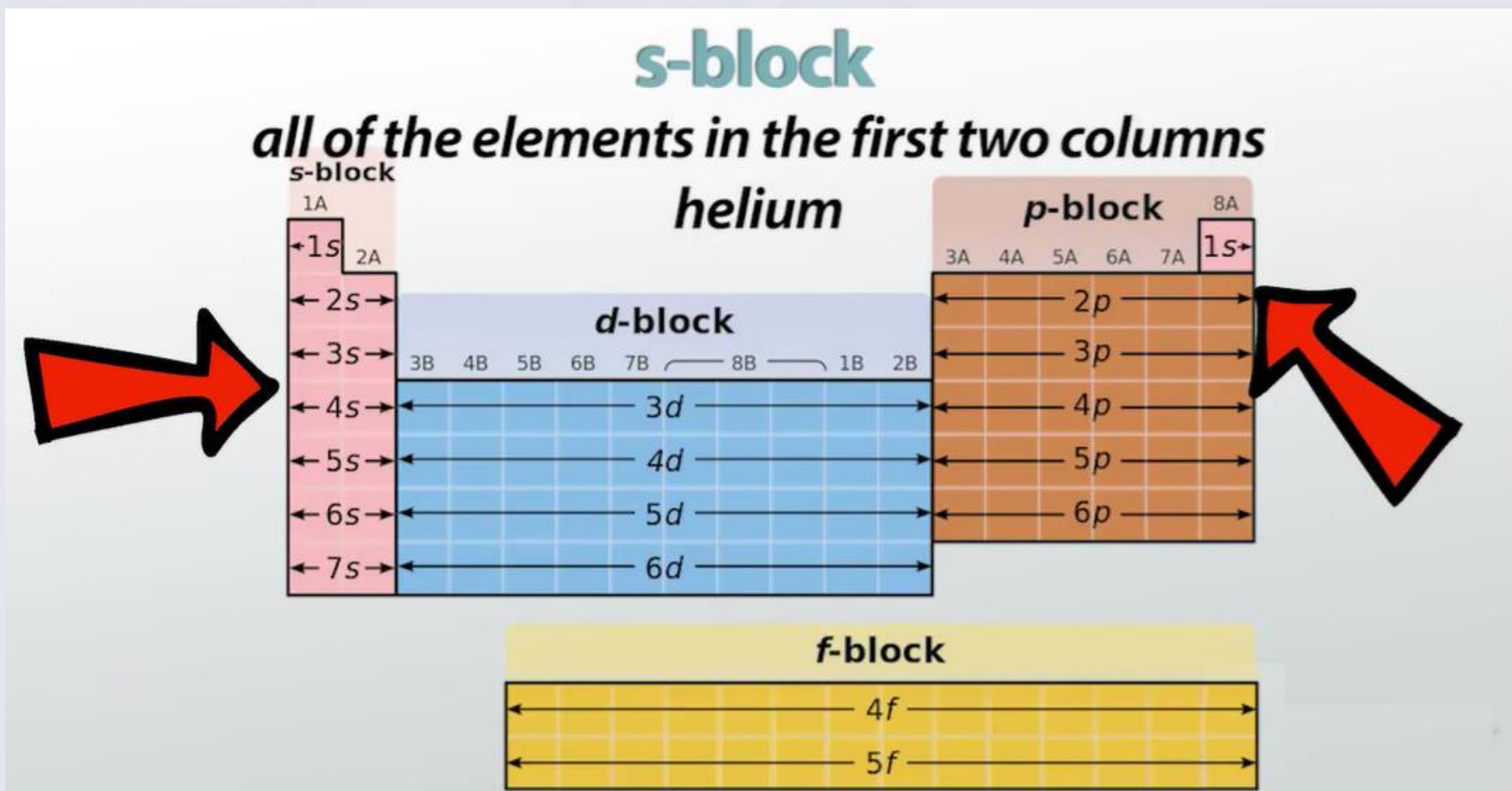
## Electron Configurations and Orbital Diagrams

### Electron Configurations



# Electron Configurations and Orbital Diagrams

## Electron Configurations



# Electron Configurations and Orbital Diagrams

## Electron Configurations

- A statement of how many electrons an atom has in each of its electron subshells.
- An oxygen atom as an electron arrangement of two electrons in the  $1s$  subshell, two electrons in the  $2s$  subshell, and four electrons in the  $2p$  subshell.

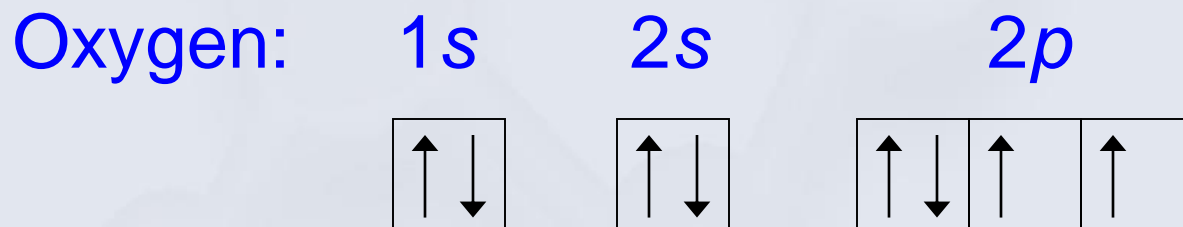
Oxygen:  $1s^2 2s^2 2p^4$

# Electron Configurations and Orbital Diagrams

## Orbital Diagrams

- A notation that shows how many electrons an atom has in each of its occupied electron orbitals.

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



# Electron Configurations and Orbital Diagrams



## Exercise

Determine the expected electron configurations for each of the following.

a) S

b) Ba

## Electron Configurations and Orbital Diagrams



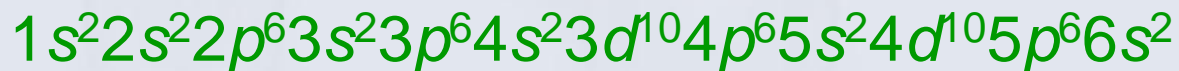
## Exercise

Determine the expected electron configurations for each of the following.

a) S



b) Ba



### The Electronic Basis for the Periodic Law and the Periodic Table

- The electron arrangement in the outermost shell is the same for elements in the same group.
- This is why elements in the same group have similar chemical properties.
  - Group 1A – very reactive

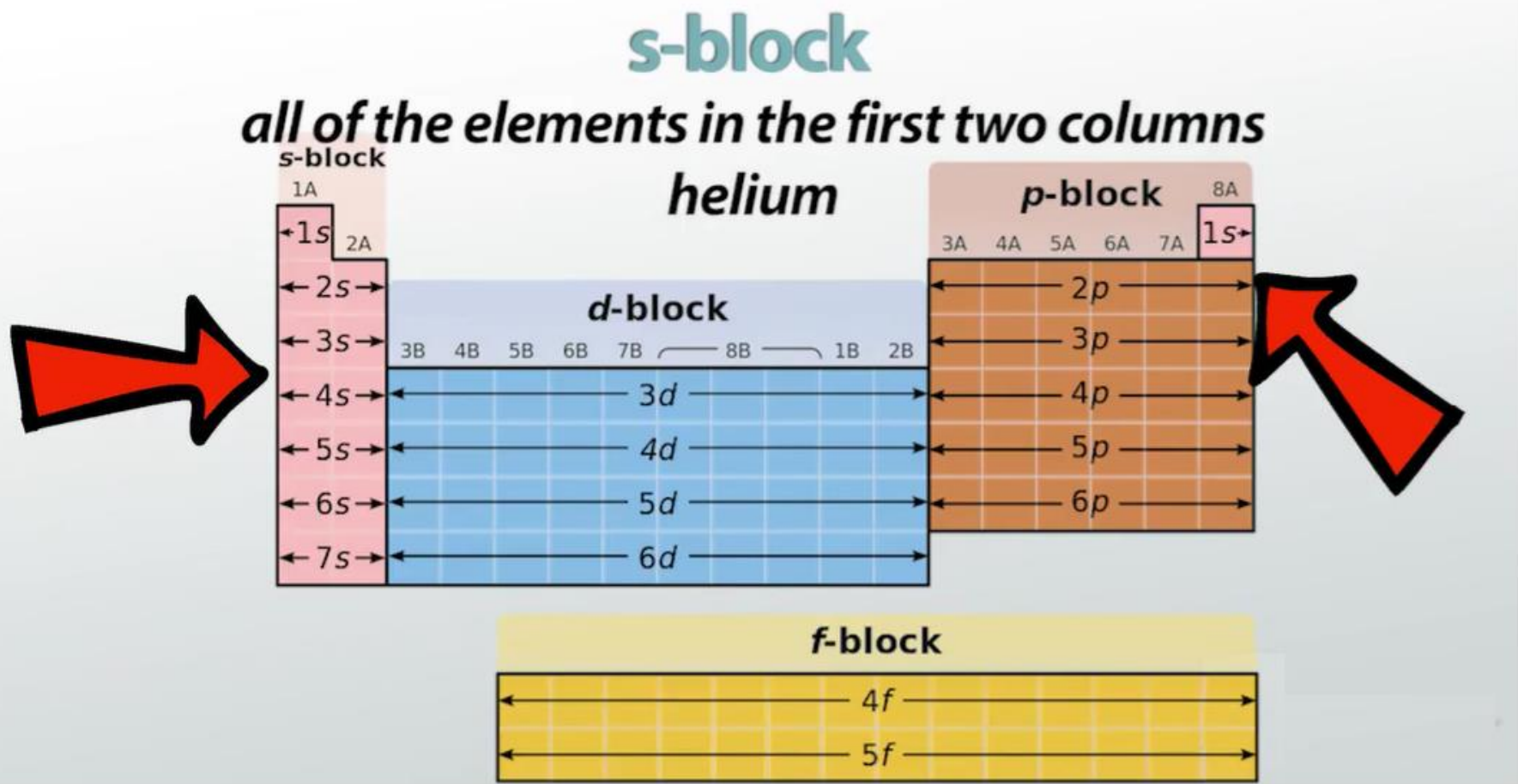
Li:  $1s^2 2s^1$

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

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

# The Electronic Basis for the Periodic Law and the Periodic Table

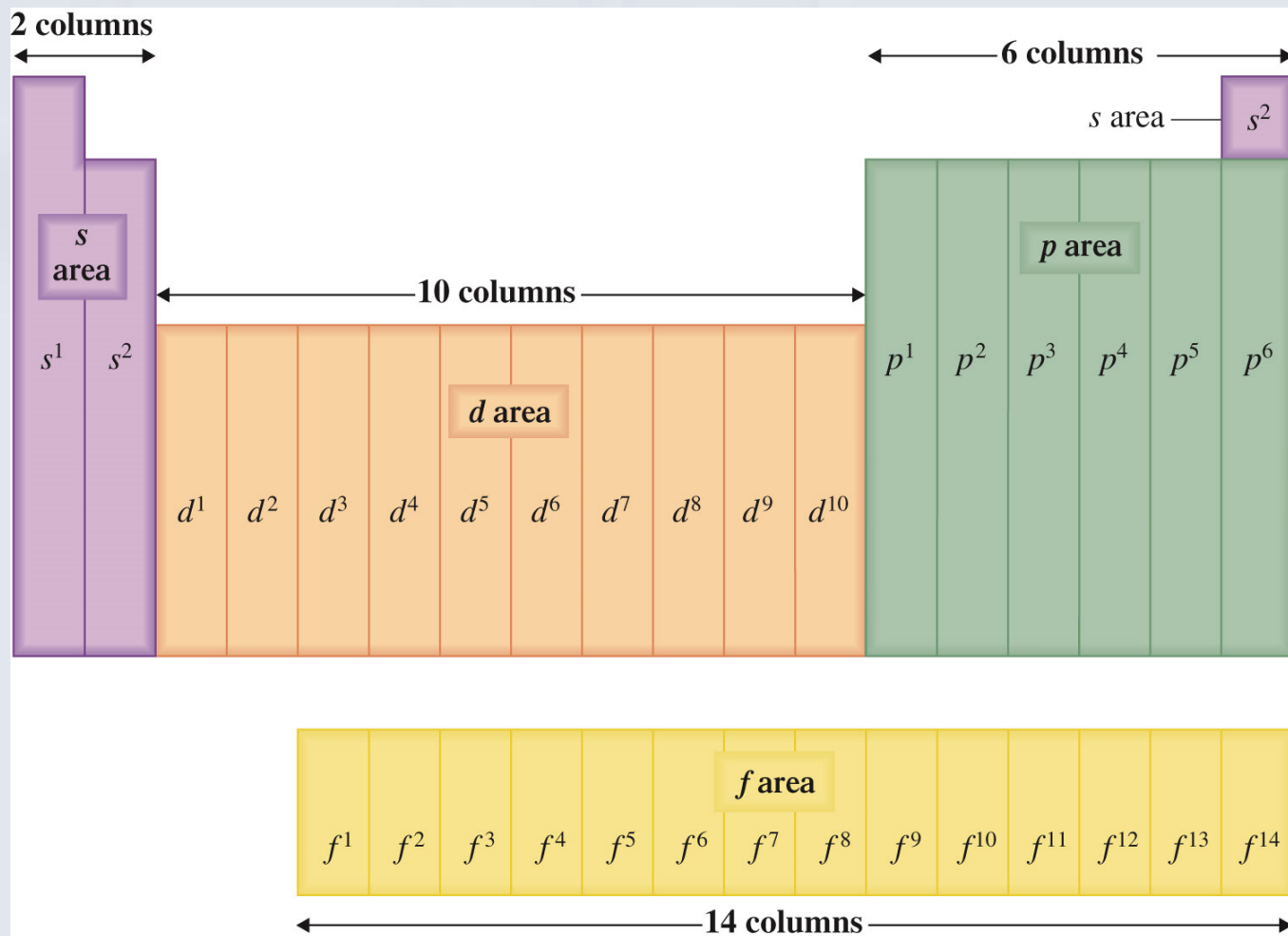
## Electron Configurations and the Periodic Table



## Section 3.8

# The Electronic Basis for the Periodic Law and the Periodic Table

## Electron Configurations and the Periodic Table



# The Electronic Basis for the Periodic Law and the Periodic Table

## Distinguishing Electron

- Last electron added to the electron configuration for an element when electron subshells are filled in order of increasing energy.
- This last electron is the one that causes an element's electron configuration to differ from that of an element immediately preceding it in the periodic table.

# Classification of the Elements

1. A system based on selected physical properties of the elements, in which they are described as metals or nonmetals.
2. A system based on the electron configurations of the elements, in which elements are described as noble-gas, representative, transition, or inner transition elements.

# Classification of the Elements

## Classification Scheme on the Periodic Table

Representative elements																Noble-gas elements					
1 H															2 He						
3 Li	4 Be															5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg															13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca															31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr															49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba															81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra															113 —	114 —	115 —	116 —	117 —	118 —