CHAPTER 3 - COMPOUNDS

- Electronic structure of the atom (3.2, 3.3)
- Ions (3.1, 3.4)
- Ionic compounds (3.4)
- Covalent bonds (3.5)
- Molecules (3.6)
- Calculations with compounds (3.7)

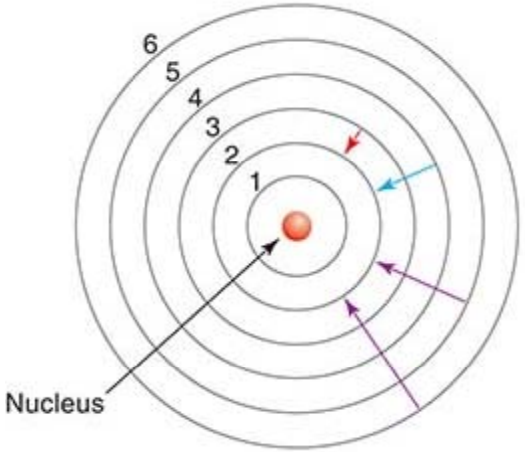
Atomic Emission Spectra

Fig. 3.1

- Gaseous element is excited with electric charge
- Excited electrons relax by emitting photons (light)
- Discrete wavelengths of light are produced, indicating electrons exist with discrete energies

Bohr's explanation

Each wavelength corresponds to different energy levels (shells) that electrons can occupy



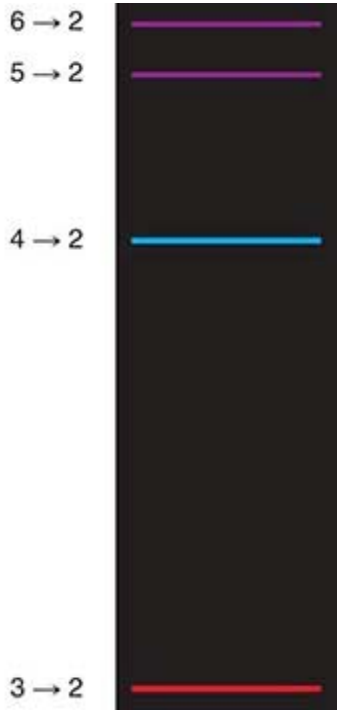


Fig. 3.3

Can only explain the emission spectrum for hydrogen

The Quantum Mechanical model

- Atomic orbitals
  - Describe regions where electrons may be found
  - Have different shapes and energies
  - Energy levels are discrete

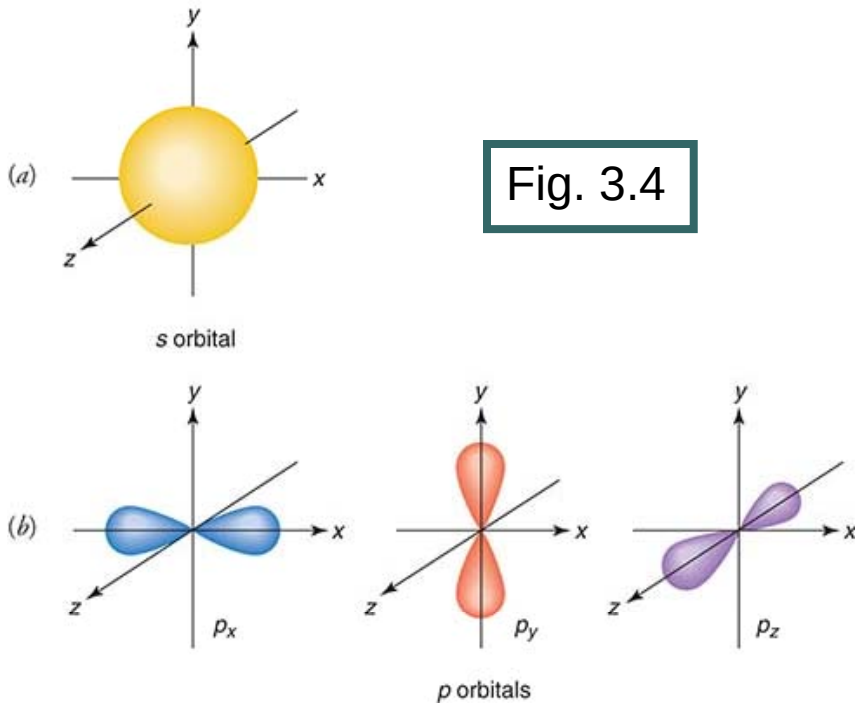


Fig. 3.4

Principal energy levels, n

TABLE 3-3

The Maximum Number of Electrons Held in the First Four Electron Energy Levels

Energy Level (n)	Maximum Number of Electrons ($2n^2$)
1	2
2	8
3	18
4	32

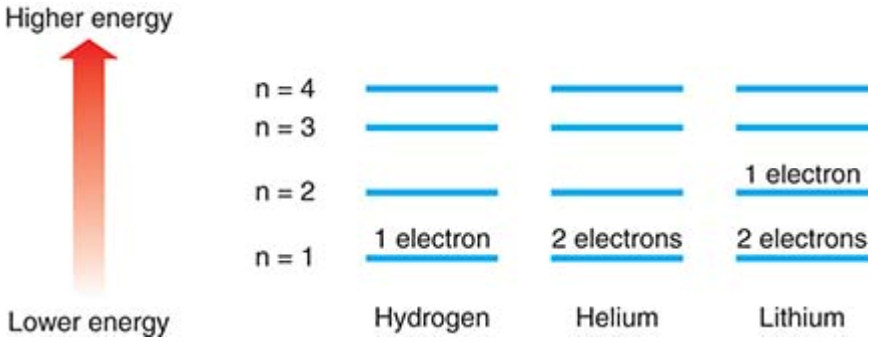
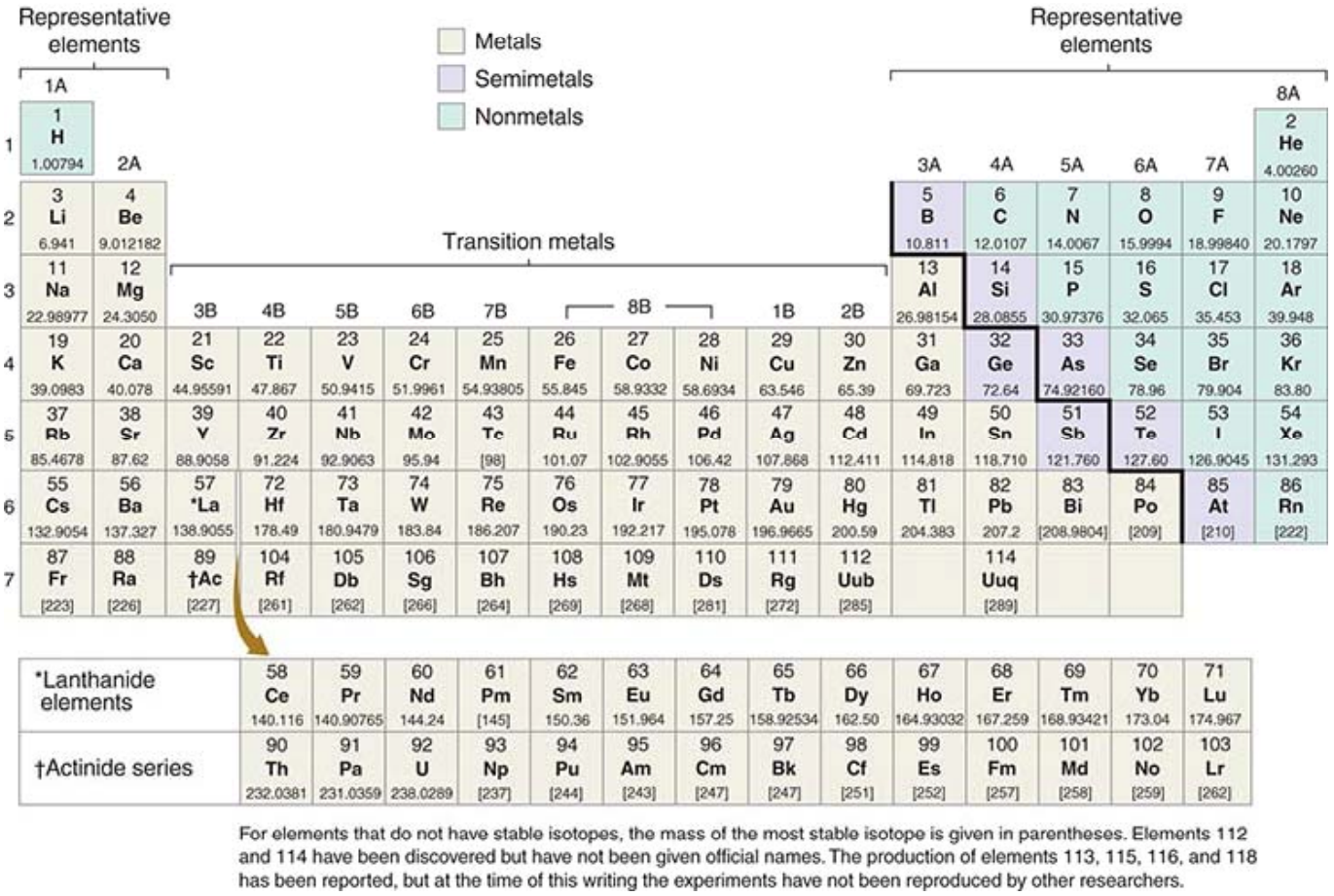


Fig. 3.5

The Periodic Table

Groups

Periods



For elements that do not have stable isotopes, the mass of the most stable isotope is given in parentheses. Elements 112 and 114 have been discovered but have not been given official names. The production of elements 113, 115, 116, and 118 has been reported, but at the time of this writing the experiments have not been reproduced by other researchers.

TABLE 3.4 The Ground State Electron Distribution for the First 20 Elements[a]

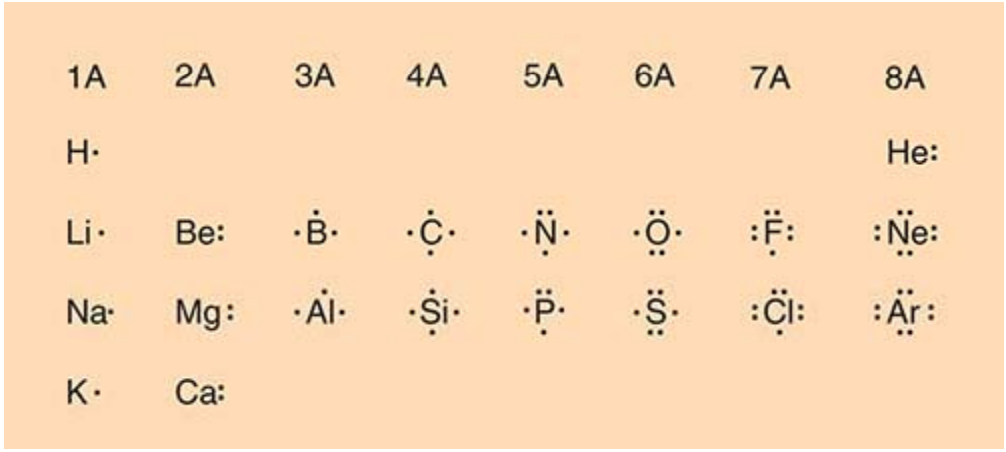
Element	Group	Number of Electrons in Energy Level			
		n=1	n=2	n=3	n=4
H	1A	**1**			
He	8A	**2**			
Li	1A	2	**1**		
Be	2A	2	**2**		
B	3A	2	**3**		
C	4A	2	**4**		
N	5A	2	**5**		
O	6A	2	**6**		
F	7A	2	7		
Ne	8A	2	**8**		
Na	1A	2	8	**1**	
Mg	2A	2	8	**2**	
Al	3A	2	8	**3**	
Si	4A	2	8	**4**	
P	5A	2	8	**5**	
S	6A	2	8	**6**	
Cl	7A	2	8	7	
Ar	8A	2	8	**8**	
K	1A	2	8	8	**1**
Ca	2A	2	8	8	**2**

[a] Valence electrons are listed in bold.

These fill before n=3 is full

Valence electrons

Definition: the electrons in the highest occupied shell (n energy level)



By Group: valence electrons within a group are the same and correspond to group #

By Period: valence electrons increase by one across a period. Group A elements in same period have valence electrons in the same shell.

Practice – valence electrons

- How many total electrons and how many valence electrons in each of the following:
  - K
  - Xe
  - B
  - Br
  - Al

Periodic Trends

- Size
  - Increases down a column
  - Decreases across a period
- Electronegativity
  - Decreases down a column
  - Increases across a period

Practice – periodic trends

- For each pair below, indicate which atom has the larger diameter and which has the greater electronegativity:
  - C and N
  - Na and K
  - Al and Cl
  - Ar and Kr

Ions - cations

Metals form cations to achieve filled outer shells:

- IA – alkali metals form +1 ions
- 2A – alkaline earth metals form +2 ions
- 3A – Al^{3+}

Transition metals – exception; charge is variable

- Fe^{2+}, Fe^{3+}
- Cu^{+}, Cu^{2+}

Ions – cations

- Cation names (non-transition metals) are the same as the atom name:

Na = sodium atom

Na^+ = sodium ion

Transition metals

Variable charge therefore need a system of naming.

- Old version
  - Smaller positive charge (lower oxidation state) ends in –ous
  - Larger positive charge (higher oxidation state) ends in –ic
- New version
  - Charge is indicated by a roman numeral (usually as part of the name within an ionic compound)

Transition metals

TABLE 3-1

Some Transition Metal Ions

Atom	Ion	Name	Alternative Name
Chromium	Cr^{2+}	Chromium(II) ion	Chromous ion
	Cr^{3+}	Chromium(III) ion	Chromic ion
Copper	Cu^{+}	Copper(I) ion	Cuprous ion
	Cu^{2+}	Copper(II) ion	Cupric ion
Iron	Fe^{2+}	Iron(II) ion	Ferrous ion
	Fe^{3+}	Iron(III) ion	Ferric ion
Tin	Sn^{2+}	Tin(II) ion	Stannous ion
	Sn^{4+}	Tin(IV) ion	Stannic ion

- Copper and iron ions are needed for metabolism and many other cellular functions
- Chromium (trace) is needed for metabolism; can be toxic

Chromium picolinate levels recently lowered to 35 μg/day

Ions - Anions

Representative elements form ions to achieve filled outer shells

- 7A elements form -1 ions
- 6A elements form -2 ions
- 5A elements form -3 ions

Anion names end in -ide

Practice – electronic structure of ions

- Draw LDS showing valence electrons and shell diagrams showing all electrons for both the neutral and ionic species of each of the following:
  - Cations: K, Mg, Al
  - Anions: O, F, N
- True or false:
  - Phosphide has the same electronic structure as Argon

Polyatomic ions

TABLE 3-2

Common Polyatomic Ions

	Formula	Name	Formula	Name
Cations	H_3O^+	Hydronium ion	NH_4^+	Ammonium ion
Anions	OH^-	Hydroxide ion	HSO_4^-	Hydrogensulfate (bisulfate) ion
	CO_3^{2-}	Carbonate ion	PO_4^{3-}	Phosphate ion
	HCO_3^-	Hydrogencarbonate (bicarbonate) ion	HPO_4^{2-}	Hydrogenphosphate ion
	NO_2^-	Nitrite ion	$H_2PO_4^-$	Dihydrogenphosphate ion
	NO_3^-	Nitrate ion	$Cr_2O_7^{2-}$	Dichromate ion
	SO_3^{2-}	Sulfite ion	$CH_3CO_2^-$	Acetate ion
	SO_4^{2-}	Sulfate ion	CN^-	Cyanide ion

Compound properties

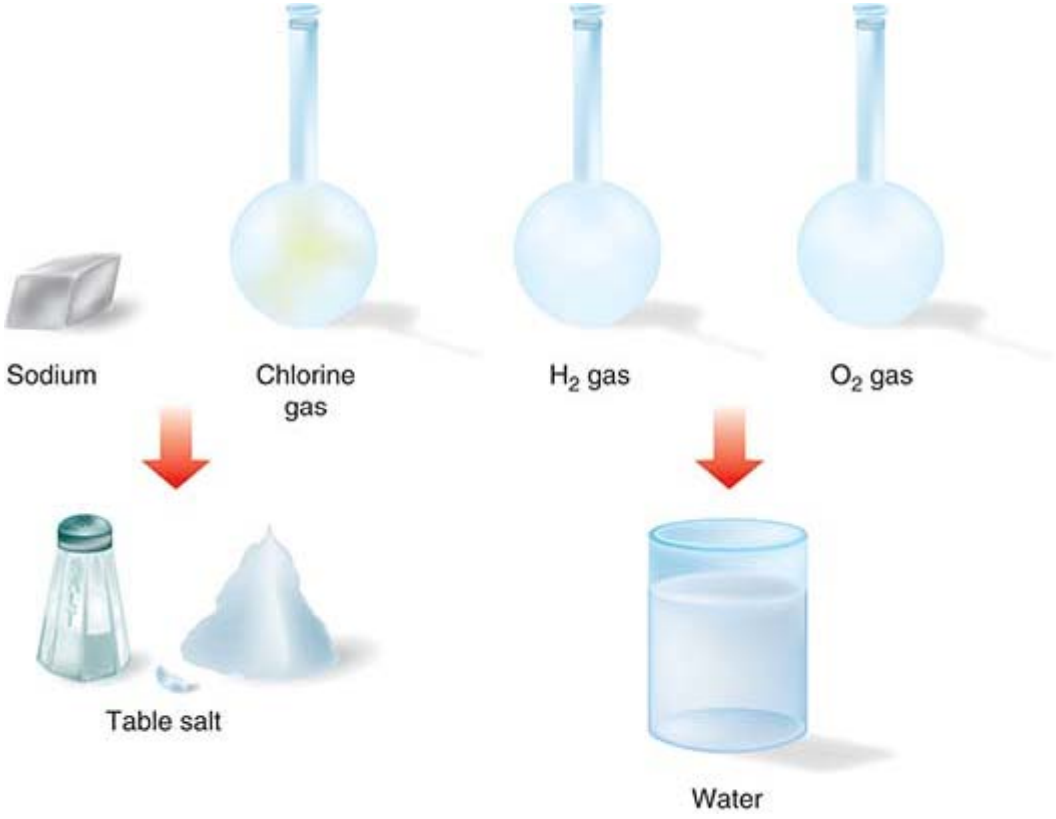


Fig. 3.11

Ionic compounds

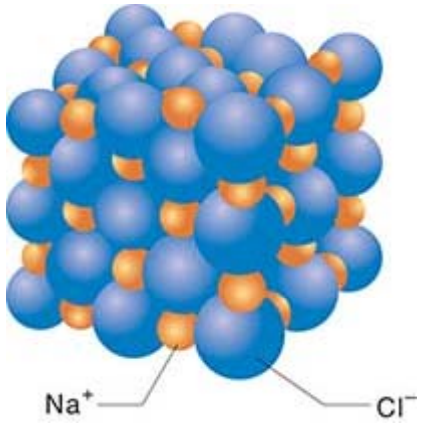


Fig. 3.13

- Ions form neutral compounds
- Ions form <u>ionic bonds</u>
  - Ionic bonds are electrostatic
- Ionic solids consist of organized lattices

Ionic compounds

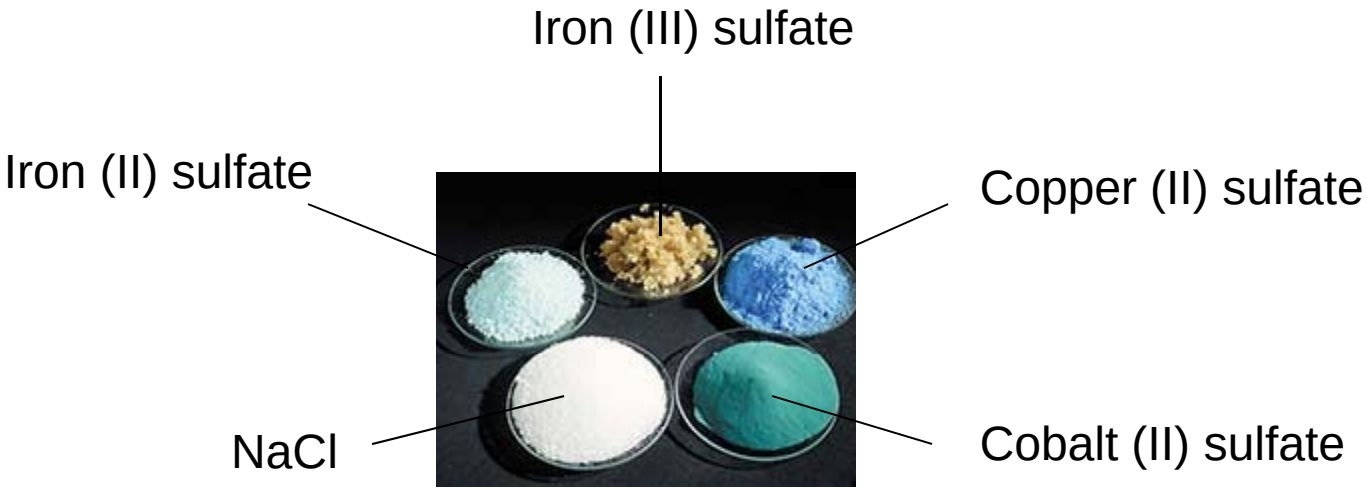


Fig. 3.14

Practice – ionic compounds, monatomic

Give constituent ions, formulas, and names of the ionic compounds that will form from:

- K and Cl
- N and K
- Ca and Cl
- P and Mg

- Most metallic element goes first in the name

Practice – Ionic compounds, polyatomic

- Name and draw the compounds that will form from the following ions:
  - Cl^- and NH_4^+
  - NH_4^+ and S^{2-}
  - Li^+ and OH^-
  - Mg^{2+} and PO_4^{3-}

Ionic compounds involving transition metals

- Names indicate the charge and the formula.
  - Iron (III) chloride, $FeCl_3$
  - Iron (II) bromide, $FeBr_2$
- The anion tells you the oxidation state of the transition metal
  - CuO = copper (II) oxide

Practice – ionic compounds involving transition metals

- Name or give the formula of the following:
  - Iron (III) sulfide
  - Fe_2O_3
  - Co (II) chloride
  - PbO
  - $Fe(NO_3)_2$

Rules for drawing structures – 1-2 central atoms

- Count total electrons each atom "wants"
- Count valence electrons each atom has.
  - If a molecule is charged add to (neg. charge) or subtract from (positive charge) the valence electrons.
- Total - valence = bonding electrons
- Valence - bonding = non-bonding electrons
- Determine the central atom (usually least EN)
- Place other atoms around central atoms
- Check octets

Practice – Drawing structures

- Worked examples:

  CH_4 CH_2O H_2S O_2

- More examples:

  C_2H_6 C_2H_2 $POCl_3$ CS_2

Practice – naming binary molecules

- Name the following molecules:
  - SO_2
  - H_2O
  - $SiBr_4$
  - P_4Se_3

Calculations with compounds - practice

- Determine the molar mass of calcium carbonate ($CaCO_3$)
- Determine the molar mass of ethanol (C_2H_6O)
- How many mol are in 5 g of CuS?
- How many atoms are in 4.5 g of glucose ($C_6H_{12}O_6$)?