Chapter 4. Chemical Bonding: The Ionic Bond Model

Introduction to Inorganic Chemistry

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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)

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Chapter 4 Chemical Bonding: The Ionic Bond Model

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Section 4.1

Chemical Bonds

A Chemical Bond

- Attractive force that holds two atoms together in a more complex unit.
- Form as a result of interactions between electrons found in the combining atoms.

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Section 4.1

Chemical Bonds

Two Types of Chemical Bonds

- Ionic Bonds (metal + non-metal) Chapter 4
- Covalent Bonds (non-metal + non-metal) Chapter 5
- Metallic Bonds (metal + metal) (not discussed)

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Section 4.1

Chemical Bonds

Ionic Bond

- Chemical bond formed through the transfer of one or more electrons from one (metal) atom or group of atoms to another (non-metal) atom or group of atoms.
- Ionic Compound
  - A compound in which ionic bonds are present due to charged attractions between cations and anions.

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Section 4.1

Chemical Bonds

Covalent Bond

- Chemical bond formed through the sharing of one or more pairs of electrons between two non-metal atoms.
- Molecular Compound (Covalent Compound)
  - A compound in which atoms are joined through covalent bonds.

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Section 4.1

Chemical Bonds

Metallic Bond

- Chemical bond formed through the sharing of one or more pairs of electrons between all atoms in a solid.
- Metals: Metallic elements

  Metallic properties are due to metallic bonding
- Alloys (Metallic compounds)
  - A compound in which atoms are joined through metallic bonds.

Section 4.1

Chemical Bonds

Bonding

- Most bonds are not 100% ionic or 100% covalent.
- Most bonds have some degree of both ionic and covalent character.

Section 4.1

Chemical Bonds

Two Fundamental Concepts

1. Not all electrons in an atom participate in bonding. Those that participate are called valence electrons.
2. Certain arrangements of electrons are more stable than others, as is explained by the octet rule.

Section 4.2

Valence Electrons and Lewis Symbols

Valence Electron

- An electron in the outermost electron shell of a representative element or noble-gas element.
- In these representative elements or nobel gases the valence electrons are found in either *s* or *p* subshells.

Section 4.2

Valence Electrons and Lewis Symbols

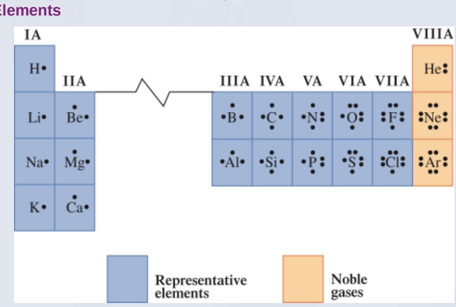
Lewis Symbol

- Chemical symbol of an element surrounded by dots equal in number to the number of valence electrons present in atoms of the element.

Section 4.2

Valence Electrons and Lewis Symbols

Lewis Symbols for Selected Representative and Noble-Gas Elements



Section 4.2

Valence Electrons and Lewis Symbols

Concept Check

Determine the number of valence electrons in each of the following elements:

Ca

Se

C

Section 4.2

Valence Electrons and Lewis Symbols

Concept Check

Determine the number of valence electrons in each of the following elements:

Ca

2 valence electrons ($4s^2$)

Se

6 valence electrons ($4s^2 4p^4$)

C

4 valence electrons ($2s^2 2p^2$)

Section 4.2

Valence Electrons and Lewis Symbols

Three Important Generalizations About Valence Electrons

1. Representative elements in the same group have the same number of valence electrons.
2. The number of valence electrons for representative elements is the same as the Roman numeral periodic-table group number.
3. The maximum number of valence electrons for any element is eight.

Section 4.2

Valence Electrons and Lewis Symbols

Concept Check

Write Lewis symbols for the following elements:

O

P

F

Section 4.2

Valence Electrons and Lewis Symbols

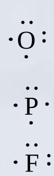
Concept Check

Write Lewis symbols for the following elements:

O

P

F



Section 4.3

The Octet Rule

- Certain arrangements of valence electrons are more stable than others.
- The valence electron configurations of the noble gases are considered the most stable of all valence electron configurations.

Section 4.3

The Octet Rule

Octet Rule (G.N. Lewis)

- In forming compounds, atoms of elements lose, gain, or share electrons in such a way as to produce a noble-gas electron configuration for each of the atoms involved.

Section 4.4

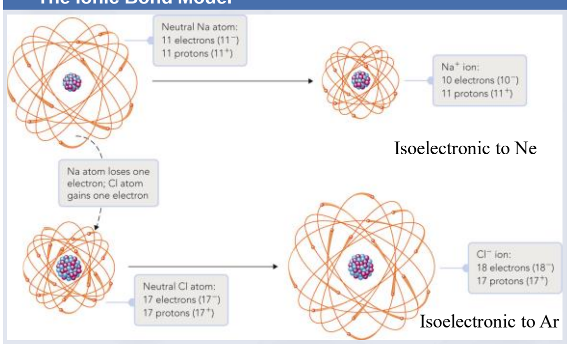
The Ionic Bond Model

Ion

- An atom (or group of atoms) that is electrically charged as a result of the loss or gain of electrons.
- If an atom *gains* one or more electrons, it becomes a *negatively* charged ion (anion).
- If an atom *loses* one or more electrons, it becomes a *positively* charged ion (cation).

Section 4.4

The Ionic Bond Model



Section 4.4

The Ionic Bond Model

Concept Check

Give the chemical symbol for each of the following ions.

a) The ion formed when a potassium atom loses one electron.

b) The ion formed when a sulfur atom gains two electrons.

Section 4.4

The Ionic Bond Model

Concept Check

Give the chemical symbol for each of the following ions.

a) The ion formed when a potassium atom loses one electron.

K^+

b) The ion formed when a sulfur atom gains two electrons.

S^{2-}

Section 4.5

The Sign and Magnitude of Ionic Charge

- Atoms tend to gain or lose electrons until they have obtained an electron configuration that is the same as that of a noble gas.
  - Example: K^+ ($1s^22s^22p^63s^23p^6$)
    - Lost one electron to obtain electron configuration for Ar ($1s^22s^22p^63s^23p^6$).

Section 4.5

The Sign and Magnitude of Ionic Charge

1. Metal atoms containing one, two, or three valence electrons tend to lose electrons to acquire a noble-gas electron configuration.

+ charge = group #

Group	Charge
IA	1+
IIA	2+
IIIA	3+

Section 4.5

The Sign and Magnitude of Ionic Charge

2. Nonmetal atoms containing five, six, or seven valence electrons tend to gain electrons to acquire a noble-gas electron configuration.

- charge = 8 – group #

Group	Charge
VIIA	1–
VIA	2–
VA	3–

Section 4.5

The Sign and Magnitude of Ionic Charge

3. Elements in Group IVA occupy unique positions relative to the noble gases (could gain or lose four electrons).

   Eg. C and Si

Section 4.5

The Sign and Magnitude of Ionic Charge

Isoelectronic Species

- A series of ions/atoms containing the same number and configuration of electrons.

O^{2-}, F^{-}, Ne, Na^{+}, Mg^{2+}, and Al^{3+}

$1s^22s^22p^6$

Section 4.5

The Sign and Magnitude of Ionic Charge

Isoelectronic Species Mg^{2+} and Ne

Table 4.1 Comparison of the Characteristics of the Isoelectronic Species Ne and Mg^{2+}

	Ne Atom	Mg^{2+} Ion
Atomic number	10	12
Protons (in the nucleus)	10	12
Electrons (around the nucleus)	10	10
Charge	0	+2

Section 4.5

The Sign and Magnitude of Ionic Charge

Concept Check

Choose an alkali metal, an alkaline earth metal, a noble gas, and a halogen so that they constitute an isoelectronic series when the metals and halogen are written as their most stable ions.

- What is the electron configuration for each species?
- Determine the number of electrons for each species.
- Determine the number of protons for each species.

Section 4.6

Lewis Structures for Ionic Compounds

Formation of an Ionic Compound

- Ion formation requires the presence of two elements:
  - A metal that can donate electrons.
  - A non-metal that can accept electrons.
- The electrons lost by the metal are the same ones gained by the nonmetal.
- The positive and negative ions simultaneously formed from such *electron transfer* attract one another.

Section 4.6

Lewis Structures for Ionic Compounds

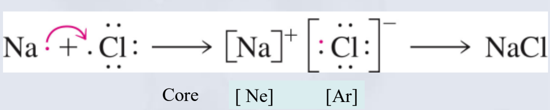
Lewis Structure

- Combination of Lewis symbols that represents either the transfer or the sharing of electrons in chemical bonds.

Section 4.6

Lewis Structures for Ionic Compounds

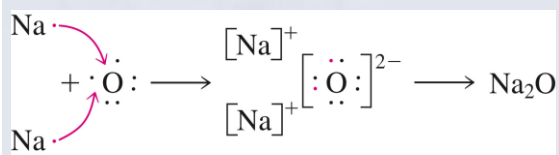
The Reaction Between Sodium and Chlorine



Section 4.6

Lewis Structures for Ionic Compounds

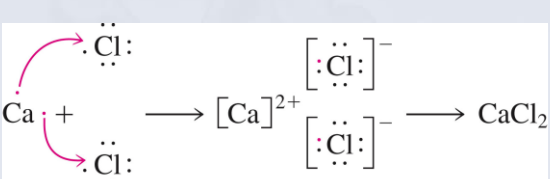
The Reaction Between Sodium and Oxygen



Section 4.6

Lewis Structures for Ionic Compounds

The Reaction Between Calcium and Chlorine



Section 4.7

Chemical Formulas for Ionic Compounds

- Ionic compounds are always neutral; no net charge is present.
- The ratio in which positive and negative ions combine is the ratio that achieves charge neutrality for the resulting compound.
- Charges on ions determines the subscripts in the formula

  Eg. Na^{1+} O^{2-} gives Na_2O

Section 4.7

Chemical Formulas for Ionic Compounds

Writing Chemical Formulas for Ionic Compounds

1. The symbol for the positive ions is always written first.
2. The charges on the ions that are present are not shown in the formula.
3. The subscripts in the formula give the combining ratio for the ions.

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Section 4.7

Chemical Formulas for Ionic Compounds

Example

- Compound formed between Li^+ and O^{2-}
  - Need two Li^+ to balance out the 2- charge on oxygen.
- Formula is Li_2O.

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Section 4.7

Chemical Formulas for Ionic Compounds

Concept Check

Determine the chemical formula for the compound that is formed when each of the following pairs of ions interact.

Ba^{2+} and Cl^-

Fe^{3+} and O^{2-}

Pb^{4+} and O^{2-}

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Section 4.7

Chemical Formulas for Ionic Compounds

Concept Check

Determine the chemical formula for the compound that is formed when each of the following pairs of ions interact.

Ba^{2+} and Cl^-

$BaCl_2$

Fe^{3+} and O^{2-}

Fe_2O_3

Pb^{4+} and O^{2-}

PbO_2

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Section 4.8

The Structure of Ionic Compounds

Solid Ionic Compounds (ionic lattices).

- Consists of positive and negative ions arranged in such a way that each ion is surrounded by nearest neighbors of the opposite charge.
- Any given ion is bonded by electrostatic attractions to all the other ions of opposite charge immediately surrounding it.

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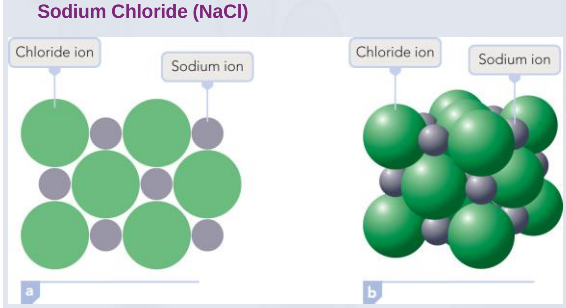
Section 4.8

The Structure of Ionic Compounds

Sodium Chloride (NaCl)



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Section 4.8

The Structure of Ionic Compounds

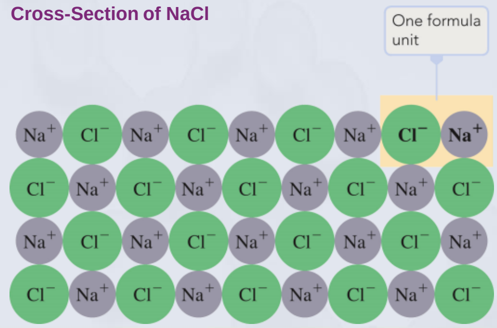
Formula Unit

- Smallest whole-number repeating ratio of ions present in an ionic compound that results in charge neutrality.
- Chemical formulas for ionic compounds represent the simplest ratio of ions present.
- Eg. Ca^{2+} O^{2-} gives Ca_2O_2 becomes CaO

Section 4.8

The Structure of Ionic Compounds

Cross-Section of NaCl



Section 4.9

Recognizing and Naming Binary Ionic Compounds

Naming Compounds

- Binary Compounds:
  - Composed of two elements
  - Ionic and covalent compounds included
- Binary Ionic Compounds:
  - Metal-nonmetal
  - Metal is always present as the positive ion, and the nonmetal is always present as the negative ion.

Section 4.9

Recognizing and Naming Binary Ionic Compounds

Naming Ionic Compounds

- The full name of the metallic element is given first, followed by a separate word containing the stem of the nonmetallic element name and the suffix *–ide*.

Section 4.9

Recognizing and Naming Binary Ionic Compounds

Names of Selected Common Nonmetallic Ions

Table 4.2 Names of Selected Common Nonmetallic Ions

Element	Stem	Name of Ion	Formula of Ion
bromine	brom-	bromide	Br^-
carbon	carb-	carbide	C^{4-}
chlorine	chlor-	chloride	Cl^-
fluorine	fluor-	fluoride	F^-
hydrogen	hydr-	hydride	H^-
iodine	iod-	iodide	I^-
nitrogen	nitr-	nitride	N^{3-}
oxygen	ox-	oxide	O^{2-}
phosphorus	phosph-	phosphide	P^{3-}
sulfur	sulf-	sulfide	S^{2-}

Section 4.9

Recognizing and Naming Binary Ionic Compounds

Examples

KCl	Potassium chloride
$MgBr_2$	Magnesium bromide
CaO	Calcium oxide

Section 4.9

Recognizing and Naming Binary Ionic Compounds

Naming Ionic Compounds (for Metals with Variable Charges)

- Metals in these compounds form more than one type of positive charge.
- Charge on the metal ion must be specified.
- Roman numeral indicates the charge of the metal cation (positively charged ion).
- Transition metal cations usually require a Roman numeral.

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Section 4.9

Recognizing and Naming Binary Ionic Compounds

Examples

CuBr	Copper(I) bromide
FeS	Iron(II) sulfide
PbO_2	Lead(IV) oxide

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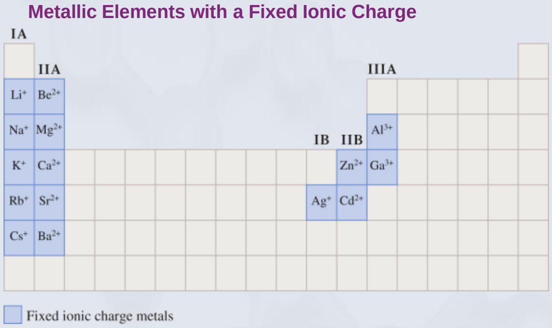
Section 4.9

Recognizing and Naming Binary Ionic Compounds

Metallic Elements with a Fixed Ionic Charge



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Section 4.9

Recognizing and Naming Binary Ionic Compounds

Exercise

Name each of the following compounds:

K_2S

Fe_2O_3

$CoCl_2$

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Section 4.9

Recognizing and Naming Binary Ionic Compounds

Exercise

Name each of the following compounds:

K_2S
potassium sulfide

Fe_2O_3
iron(III) oxide

$CoCl_2$
cobalt(II) chloride

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Section 4.10

Polyatomic Ions

Polyatomic Ion

- Ion formed from a group of atoms (held together by covalent bonds) through loss or gain of electrons.

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Section 4.10

Polyatomic Ions

Polyatomic Ion

- Common Polyatomic Ions -

ion	name	ion	name
NH_4^+	ammonium	CO_3^{2-}	carbonate
NO_2^-	nitrite	HCO_3^-	hydrogen carbonate†
NO_3^-	nitrate	ClO^-	hypochlorite
SO_3^{2-}	sulfite	ClO_2^-	chlorite
SO_4^{2-}	sulfate	ClO_3^-	chlorate
HSO_4^-	hydrogen sulfate	ClO_4^-	perchlorate
OH^-	hydroxide	$C_2H_3O_2^-$	acetate
CN^-	cyanide	MnO_4^-	permanganate
PO_4^{3-}	phosphate	$Cr_2O_7^{2-}$	dichromate
HPO_4^{2-}	hydrogen phosphate	CrO_4^{2-}	chromate
$H_2PO_4^-$	dihydrogen phosphate	O_2^{2-}	peroxide

Section 4.10

Polyatomic Ions

Polyatomic Ions

- Must be memorized (see Table 4.3 on pg. 99 in text).
- Examples of compounds containing polyatomic ions:

NaOH	Sodium hydroxide
$Mg(NO_3)_2$	Magnesium nitrate
$(NH_4)_2SO_4$	Ammonium sulfate

Section 4.10

Polyatomic Ions

Generalizations

1. Most of the polyatomic ions have a negative charge.
2. Two of the negatively charged polyatomic ions, OH^- and CN^-, have names ending in *–ide* and the rest of them have names ending in either *–ate* or *–ite*.

Section 4.10

Polyatomic Ions

Generalizations

3. A number of *–ate*, *–ite* pairs of ions exist. The *–ate* ion always has one more oxygen atom than the *–ite* ion. Both the *–ate* and *–ite* ions of a pair carry the same charge.
4. A number of pairs of ions exist wherein one member of the pair differs from the other by having a hydrogen atom present. In such pairs, the charge on the ion that contains hydrogen is always 1 less than that on the other ion.

Section 4.11

Chemical Formulas and Names for Ionic Compounds Containing Polyatomic Ions

- Determined in the same way as those for ionic compounds that contain monatomic ions.
- The positive and negative charges present must add to zero.
  - Na^+ and OH^- form NaOH.
  - Mg^{2+} and NO_3^- form $Mg(NO_3)_2$.
  - NH_4^+ and SO_4^{2-} form $(NH_4)_2SO_4$.

Section 4.11

Chemical Formulas and Names for Ionic Compounds Containing Polyatomic Ions

Exercise

Which of the following compounds is named incorrectly?

a) KNO_3 potassium nitrate
b) TiO_2 titanium(II) oxide
c) $Sn(OH)_4$ tin(IV) hydroxide
d) $(NH_4)_2SO_3$ ammonium sulfite
e) $CaCrO_4$ calcium chromate

Section 4.11

Chemical Formulas and Names for Ionic Compounds Containing Polyatomic Ions

Exercise

Which of the following compounds is named incorrectly?

a) KNO_3 potassium nitrate
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c) $Sn(OH)_4$ tin(IV) hydroxide
d) $(NH_4)_2SO_3$ ammonium sulfite
e) $CaCrO_4$ calcium chromate

titanium(IV) oxide