Lesson 10: Ionic Bonding

metal cations & nonmetal anions

Formation of Ionic Bonds:

- All "bonding" (ionic and covalent only) occurs when electrons are either shared or taken. Bonding cannot occur without _____________________.
- The electrons are transferred from the ____________________________ to the _____________________________.
- Cations (positive ions) ____________________________ and anions __________________________
- Both ions that form usually have a ____________________________
- Ionic bonds are ____________________________ between opposite charges.
- Ionic compounds are also called ____________________________.
- Most metals have ____________________________ and lose electrons easily; nonmetals have ____________________________, so they gain electrons ____________________________.
- All substances must be ____________________________ – so within a compound, the total number of ____________________________ on its cations must ____________________________ the total number of negative charges on its anions. This is the "zero charge rule."

Write the longhand electron configurations of each ion and write its charge:

1. Ion of Potassium: ____________________________________________ Charge: _________
2. Ion of Oxygen: ____________________________________________ Charge: _________
3. Ion of Lithium: ____________________________________________ Charge: _________
4. Ion of Sulfur: ____________________________________________ Charge: _________
Balancing Charges:

How many sulfur ions would be needed to balance out the positive charge of two lithium ions?

How many nitrogen ions would be needed to balance out the positive charge of three magnesium ions?

Three ways to represent electron transfer in the formation of ions:

1. Longhand electron configurations:

\[
\begin{align*}
\text{Li} & : 1s^2 2s^1 + \text{F} : 1s^2 2s^2 2p^5 & \rightarrow & \text{Li}^+ : 1s^2 + \text{F}^- : 1s^2 2s^2 2p^6
\end{align*}
\]

2. Orbital diagrams:

3. Lewis Dot Structures:

Properties of Ionic Compounds:

- ions are in a tightly bound three dimensional lattice structure
- (ionic bonds are very strong)
- (strength of ionic bond prevents ions from freely moving in the solid state)
- most ionic salts
- ionic compounds (salts) are excellent conductors of electricity and heat because
Chemical Formulas:
Chemists talk about the **smallest ratios of the ions** in ionic compounds. We’ll be working with
________________________________ which indicate the types of atoms present and the
____________________________________ of the number of atoms (or ions) in the compound. NaCl
does not have a single ionic bond, it consists of a consistent arrangement of equal numbers of Na+ cations and
Cl- anions

Predicting Formulas of Ionic Compounds
Predict the empirical formula of the ionic compound formed between the following cation/anion pairs:

<table>
<thead>
<tr>
<th>Cation + Anion pair</th>
<th>Charges of each</th>
<th>Zero Charge Rule</th>
<th>Empirical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum + Oxygen</td>
<td></td>
<td></td>
<td>LCM</td>
</tr>
<tr>
<td>Calcium + Chlorine</td>
<td></td>
<td></td>
<td>LCM</td>
</tr>
<tr>
<td>Aluminum + Fluorine</td>
<td></td>
<td></td>
<td>LCM</td>
</tr>
<tr>
<td>Magnesium + Phosphorus</td>
<td></td>
<td></td>
<td>LCM</td>
</tr>
<tr>
<td>Gallium + Nitrogen</td>
<td></td>
<td></td>
<td>LCM</td>
</tr>
</tbody>
</table>
Nomenclature of Binary Ionic Compounds (only contains 2 types of ions)

**Binary Compound with Monoatomic Ions:**

Name of the **cation** (the name of the metal) followed by the name of the **anion** (the name of the nonmetallic element with its ending replaced by the suffix –ide)

Name the ions. Circle the anions.

\[
\begin{align*}
\text{Al}^{3+} &= \hspace{1em} \text{__________________________} \\
\text{O}^2- &= \hspace{1em} \text{__________________________} \\
\text{F}^- &= \hspace{1em} \text{__________________________} \\
\text{S}^{2-} &= \hspace{1em} \text{__________________________} \\
\text{Cl}^- &= \hspace{1em} \text{__________________________} \\
\text{Mg}^{2+} &= \hspace{1em} \text{__________________________}
\end{align*}
\]

**Binary I Ionic Compounds**

The metal cation has only _____ charge possible.

These contain metals of main group metals (Groups 1A, 2A) and the “triangle metals”

Name the compounds:

\[
\begin{align*}
\text{LiCl} &= \hspace{1em} \text{__________________________} \\
\text{AgCl} &= \hspace{1em} \text{__________________________} \\
\text{KBr} &= \hspace{1em} \text{__________________________} \\
\text{KI} &= \hspace{1em} \text{__________________________} \\
\text{K}_2\text{S} &= \hspace{1em} \text{__________________________} \\
\text{BaO} &= \hspace{1em} \text{__________________________} \\
\text{BeF}_2 &= \hspace{1em} \text{__________________________} \\
\text{Zn}_3\text{N}_2 &= \hspace{1em} \text{__________________________}
\end{align*}
\]

Write the formulas:

Space to draw the “see-saw” for the zero charge rule.

zinc oxide

cadmium bromide

beryllium chloride

sodium fluoride

silver iodide
Binary II Ionic Compounds

The metal cation has ______________ possible charge.

_In the name only_, following the name of the metal, the ______________ of the metal must be included as a ______________. Anions still have “ide” ending.

For the _chemical formulas_ of Binary II Ionic compounds, follow the same rules as Binary I – _no Roman numerals_ in the empirical formulas.

**Examples:** Write the empirical formula for each compound.

1. copper (II) iodide  ___________________

2. gold (III) chloride  ________________

**Examples:** Name each compound.

1. FeCl₃  __________________________________

2. V₂O₅  ________________________________
Practice: Write the name or the empirical formula for each ionic compound. Use extra space to use the “see-saw” and follow the zero charge rule.

1. FeS

2. Fe₂S₃

3. SnF₄

4. MnS₂

5. Au₂O

6. ScCl₃

7. vanadium (V) chloride

8. lead (IV) sulfide

9. thallium (I) iodide

10. cobalt (III) oxide

11. chromium (III) nitride
Ionic Compounds with Polyatomic Ions

that have either _____________________________.

They are ions ____________________________ that act as one unit with a _________________________.

_________________________ = polyatomic ions containing oxygen

Polyatomic Ions to MEMORIZE:

1. Ammonium
2. Acetate
3. Hydroxide
4. Hypochlorite*
5. Chlorite*
6. Chlorate*
7. Perchlorate*
8. Nitrate
9. Nitrite
10. Sulfate
11. Sulfite
12. Carbonate
13. Phosphate

Nomenclature: Use the name of the polyatomic ion itself in the naming. For polyatomic cations, still add “ide” for the anion.

Chemical Formulas: Subscripts on the polyatomic ions are ________________________________.

Use ______________________________ with an outer subscript to denote more than one polyatomic ion.

Example: Ca(NO₂)₂ is calcium nitrite, it has one calcium cation and two nitrite anions.
BOX 1: UNDERSTANDING CHEMICAL FORMULAS:

**CrPO**₄ is the chemical formula for chromium (III) phosphate.

How many Cr ions? _____
How many phosphate ions? ______
How many oxygen atoms? _____

**Mg(C₂H₃O₂)₂** is the chemical formula for magnesium acetate.

How many Mg ions? _____
How many acetate ions? _____
How many carbon atoms? _____
How many hydrogen atoms? _____

**Examples of Ionic Compound with Polyatomic Ions:** Write the empirical formula for each compound.

1. Calcium carbonate  ____________________

```
cations  anions
[ ]   [ ]  LCM
```

2. Ammonium hydroxide  ________________

```
cations  anions
[ ]   [ ]  LCM
```

3. Aluminum nitrate  ____________________

```
cations  anions
[ ]   [ ]  LCM
```
Examples: Name each compound

1. HgSO₄
   __________________________

2. Mn₃(PO₄)₂
   __________________________

3. KOH
   __________________________

Intro to Lewis Dot Symbols:

Guidelines:
- dots are used to represent electrons
- **only valence electrons are included**
- cations ➔ no dots & and positive charge
- anions ➔ will have a filled valence shell (8) & a negative charge

\[ \text{K}^+ \quad :\text{Br}^- \]

STEPS:
1. Find the number of valence electrons (A group elements = group number)
2. Write the element symbol.
3. Draw dots starting at the top (or right) of the symbol and continue clockwise.
EXAMPLES:

1. Gallium
   Group # __________  How many valence electrons? __________

2. Sulfur
   Group # __________  How many valence electrons? __________

3. Magnesium
4. Bromine
5. Aluminum

Lewis Structures are also used to show ions and ionic compound formation.

EXAMPLE: Draw how an ionic compound would form between Li and O to form Li$_2$O.

Li → S → [Li$^+$]$_2$[O$^{2-}$]$_2$

Oxygen needs two electrons to have a full outer shell.

Each Li atom will donate their one valence electron.

Valence shell is highlighted.

Just valence electrons

Sulfur will gain 2 electrons to have a full outer shell of 8 valence electrons.

Superscript indicates overall charge.

Subscript indicates two Li$^+$ ions.
Draw how an ionic compound would form between Ca and F to form CaF$_2$.

Draw how an ionic compound would form between Na and Cl to form NaCl.

**Review & Practice:**

Draw Lewis Dot Diagrams to show how ions and ionic bonds are formed between the following elements. Then, write final chemical formula of compound that is formed.

1. K and S

2. Mg and P

3. Ba and Br
BOX 2. Given the following formulas, predict the formula for the compound formed with another element within the same group:

Example: If $K_2O$ is potassium oxide, what is the chemical formula for rubidium oxide?

$K$ and $Rb$ are in the same group (1A) so they both form $+1$ ions. If two $K^+$ ions balance out one $O^{2-}$ ion, then two $Rb^+$ ions will balance out one $O^{2-}$ ion. Answer: $Rb_2O$.

1. If $CaSO_4$ is calcium sulfate, what is the chemical formula for barium sulfate?

2. If $Li_2Se$ is lithium selenide, what is the chemical formula for cesium selenide?

3. If $Be(OH)_2$ is beryllium hydroxide, what is the chemical formula for strontium hydroxide?

4. If $K_3PO_4$ is potassium phosphate, what is the chemical formula for lithium phosphate?

5. If $Ba(C_2H_3O_2)_2$ is barium acetate, what is the chemical formula for beryllium acetate?

BOX 3. Spelling counts!! Write out the following ions (element symbol + charge):

nitride

sulfide

chloride
	nitrite
	sulfite

chlorite
	nitrate

sulfate

chlorate

VOCABULARY:

- binary compound: compound containing two different elements.
- covalent bond: attractive force between the nuclei of a molecule’s atoms and pairs of electrons between the atoms.
- empirical formula: formula showing the composition of a compound given as the simplest whole-number ratio of atoms.
- ionic bond: electrostatic forces of attraction between the oppositely charged ions of an ionic compound.
- ionic compound: compound composed of cations and anions combined in ratios, yielding an electrically neutral substance.
- main group element: (also, representative element) element in columns 1, 2, and 12–18.
- molecular formula: formula indicating the composition of a molecule of a compound and giving the actual number of atoms of each element in a molecule of the compound.
- monoatomic ion: ion composed of a single atom.
- oxyanion: polyatomic anion composed of a central atom bonded to oxygen atoms.