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Ionic Formula Writing Kit

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Introduction:

In this activity, you will cut out cation and anion cards and combine them in the correct ratio to form a neutral ionic compound. The chemical formula and the name of the compound will then be written. This activity leads to the discovery of a systematic method of writing formulas for ionic compounds without the need to experimentally determine each formula.

Background:

The *chemical formula* of a compound indicates the kinds of atoms and the relative number of each atom that is combined together to form the compound. *Subscripts* are the numbers written after the chemical element symbols and are used to indicate the number of atoms of each element in the compound. Water, the most abundant chemical on Earth, has the chemical formula H_2O and has a whole-number hydrogen:oxygen atom ratio of 2 to 1.

Some compounds such as sodium chloride, which is common table salt, are composed of *ions*. Ions are atoms or groups of atoms that have a net positive or negative charge. *Cations* are atoms or groups of atoms with a net positive charge, such as Cu^{2+} or NH_4^+, while *anions* are atoms or groups of atoms with a net negative charge, such as O^{2-} or NO_3^-. Atoms of metallic elements tend to form cations while atoms of nonmetallic elements tend to form anions. Ions join together because of an oppositely-charged or electrostatic attraction between a positive cation and a negative anion resulting in an *ionic bond*. Compounds held together by ionic bonds are *ionic compounds*.

Ionic compounds are generally composed of an extended network of positively-charged metal ions and negatively-charged nonmetal ions. Although composed of ions, ionic compounds are electrically neutral, i.e., the total positive charge is equal to the total negative charge. The chemical formula indicates the smallest whole-number ratio of each element in the network of ions and is called a *formula unit*. For example, magnesium chloride has the chemical formula $MgCl_2$. The magnesium cation (Mg^{2+}) and chloride anions (Cl^-) combine in a 1:2 ratio to form $MgCl_2$. The overall charge on the resulting ionic compound is zero. Thus the final compound is composed of two Cl^- ions for each Mg^{2+} ion.

Some ions consist of a group of covalently bonded atoms that tend to stay together as if they were a single ion. Such ions are called *polyatomic ions*. An example is the nitrate ion, NO_3^-. This polyatomic anion contains one nitrogen atom covalently bonded to three oxygen atoms and has an overall charge of –1. Calcium cations, Ca^{2+}, in the presence of nitrate anions, NO_3^-, will combine in a ratio of two nitrate ions for every calcium ion in order to balance the positive and negative charges and achieve electrical neutrality. Thus the formula for calcium nitrate is written as $Ca(NO_3)_2$, showing that for every calcium ion there are two nitrate ions. Notice that the polyatomic ion is put in parentheses as a unit with the subscript on the outside of the parentheses.

Writing Formulas for Ionic Compounds:

1. The cation is always written first; the anion is written second.
2. The overall charge for an ionic compound is always zero. The charges of the individual ions are never included in the compound's formula.
3. Subscripts are used to indicate the number of atoms of each element in the compound.
4. Parentheses are used around polyatomic ions to show that the subscript pertains to the polyatomic ion as a whole.
5. Assumed subscripts of one are omitted when writing chemical formulas.

Naming Ionic Compounds:

1. *Naming Cations*

   A. *Naming cations with one ionic charge:*

   The name of the cation is exactly the same as the name of the element. Thus a lithium atom (Li) forms a lithium cation (Li^{+}) and a magnesium atom (Mg) forms a magnesium cation (Mg^{2+}).

   B. *Naming cations with more than one ionic charge:*

   Some transition metal ions can form more than one common ionic charge (e.g., Cu^{+} and Cu^{2+}). Two methods of naming such cations are used. A common method, and the method used in this activity, is called the *Stock system*. A Roman numeral in parentheses is used as part of the name of the element to indicate the numerical value of the charge. Thus the cation Cu^{+} is the copper(I) ion and is read as "copper one" ion while Cu^{2+} is the copper(II) ion and is read as "copper two" ion. The older, Latin-based method of naming these cations is called the *Classical system*. This system uses a root word with different suffixes at the end of the word. The suffix *-ous* is used for the name of the cation with the lower of the two ionic charges while the suffix *-ic* is used with the higher of the two ionic charges. Using this system, Cu^{+} is the cupr*ous* ion and Cu^{2+} is the cupr*ic* ion.

2. *Naming Anions*

   The name of an anion is not the same as the element name. The name of the anion ends in *-ide*. Thus a sulfur atom (S) forms a sulfide anion (S^{2-}) and an chlorine atom (Cl) forms a chloride anion (Cl^{-}).

Chemical Concepts:

- Formula writing
- Ionic compounds
- Cations and anions

Materials Needed:

Sheet of cations	Data Table
Sheet of anions	Scissors
Ion Formula Chart	Envelope

Pre-Lab:

1. Working in teams or individually, cut all of the positive ion cards from the cation sheet and all of the negative ion cards from the anion sheet. Separate the cations from the anions.
2. Observe carefully the ion cards that have been cut. What do you notice about the height of the cards? What is the relationship between the height and the ion charge?

Procedure:

1. Locate the data table and the Ion Formula Chart.

2. From the cation and anion cards that were cut, locate ion cards for the first two combining ions listed in the first column of the data table. The first two, for example, are the aluminum cation and chloride anion. Copy the ionic formula for each ion into the first column of the data table. Use the Ion Formula Chart to look up the ion formulas.

3. Put the cards for the two combining substances together on a flat surface adding additional cards of the same ion until the heights of the cation and anion column are equal. For example, every aluminum cation needs three chloride anions. *(See Figure 1.)*

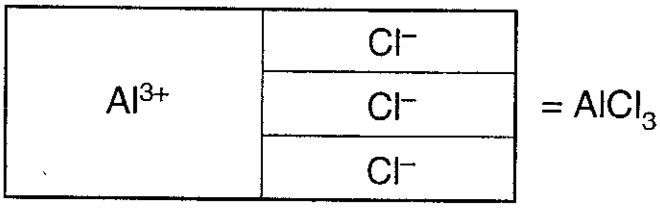

Figure 1: **Aluminum chloride**

4. Count the number of each ion necessary for the heights to be equal (i.e., for the compound to form). For example, one aluminum cation combines with three chloride anions. Record the number of each ion used in Columns 2 and 3 of the data table. Notice that the numbers recorded in Columns 2 and 3 are the subscripts in the chemical formula of the compound.

5. Determine the total positive charge of the cation card(s) and the total negative charge of the anion card(s) used in forming the compound. These two values will be equal yet opposite in value. For example, the total positive charge is +3 (from one aluminum with a +3 charge) and the total negative charge is –3 (from three chlorides, each with a –1 charge). Record the ionic charges in Columns 4 and 5 of the data table.

6. Write the formula for the ionic compound, using subscripts to indicate the number of each kind of ion used (from Columns 2 and 3). Follow the rules for writing ionic formulas listed in the background material. In our example, the formula is $AlCl_3$. Record the chemical formula for the ionic compound in Column 6 of the data table.

7. Write the name of the ionic compound following the rules for naming ionic compounds discussed in the background information. In our example, the name of the compound is aluminum chloride. Record the name for the ionic compound in the last column of the data table.

8. Repeat steps 2–7 for each set of combining ions in the data table.

9. After writing formulas for all 16 sets of combining ions listed in the data table, complete rows 17–20 of the data table by randomly choosing four more sets of combining ions (that have not already been combined). Follow the procedure in steps 2–7 to complete each column of the data table.

10. Gather the ion cards. Place them in an envelope and return the ion cards to the instructor.

Data Table

Name: ______________________

Combining Ions	Number of cations	Number of anions	Total + charge	Total – charge	Formula	Name of compound
1. Aluminum & Chloride						
2. Sodium & Oxide						
3. Iron(II) & Sulfide						
4. Potassium & Sulfate						
5. Silver & Nitrate						
6. Copper(II) & Hydroxide						
7. Ammonium & Carbonate						
8. Copper(I) & Phosphate						
9. Magnesium & Bromide						
10. Calcium & Acetate						

Data Table continued

Name: ______________________

Combining Ions	Number of cations	Number of anions	Total + charge	Total – charge	Formula	Name of compound
11. Iron(III) & Oxide						
12. Copper(I) & Chromate						
13. Sodium & Bicarbonate						
14. Magnesium & Phosphate						
15. Potassium & Cyanide						
16. Aluminum & Sulfide						
17.						
18.						
19.						
20.						

Name: ______________________________

Questions and Analysis of Data:

1. Examining the combining substances and formulas you wrote in your data table, develop a general procedure explaining how to write a formula for an ionic compound.

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2. Using the procedure that you wrote in question #1, write the chemical formula for each of the following combining substances. (*Hint:* First look up the cation and the anion formulas from the Ion Formula Chart; then write the ionic formula.)

Combining Substances	Cation and Anion Formulas	Ionic Formula
a) lithium and dichromate		
b) strontium and bromate		
c) gallium and oxalate		
d) mercury(I) and chloride		
e) lead(II) and nitride		

3. Using the Ion Formula Chart, create three new ionic compounds that have not yet been used in this activity. List the names of the combining substances, the cation and anion formulas, and the ionic formula.

Combining Substances	Cation and Anion Formulas	Ionic Formula
a)		
b)		
c)		