21: What Do You Call This Stuff?

Before I start you out naming chemicals, I'd like you to appreciate what it is you are going to be able to do. Once you learn how to name compounds, no chemist bully can any longer intimidate you with a name like "calcium nitrate" or "ammonium sulfate hydrate."

Perhaps some stranger will approach you and say, "Hey young lady, I have a special deal for you on ammonium nitrate, urea, ammonium polyphosphate and potassium sulfate."

You'll just look him straight in the eye and say, "No thanks, I have all the fertilizer I need!"

Way back in Lesson 2 we introduced you to the building blocks of matter which we call the elements. We also told you that, since elements combine with each other to form a wide variety of chemical compounds, it is convenient to have a shorthand method for referring to them. The symbols for each element are given in the periodic table. Furthermore, through the first nine chapters we have seen the chemical formulas for many different compounds. But how do we name those compounds? Oh, we know that many of them have "common" names, like water, salt, ammonia, etc. But there are literally millions of compounds, and we couldn't possibly hope to memorize common names for them all. Therefore, standard **nomenclatures**—systems of names—have been devised. In this lesson you will begin to learn some of the rules for naming **binary compounds**, that is, compounds that consist of only two elements.

In Lesson 10 we noted that elements can, either through the loss or gain of electrons, form ions. That information will serve you well as you try to name binary compounds. The simplest situation in terms of naming binary compounds is when one of the elements is a metal that can form only one kind of cation.

In earlier studies of chemistry or of physical science, you learned that a metal is described as a substance having a series of characteristics, namely:

1) conduct heat and electricity
2) having surfaces that, when polished, reflect light
3) ductile and malleable

The metallic elements occupy the entire left side of the periodic table (See Figure 1), including group IA, IIA and all the B groups. A few of the post-transition elements behave like metals as well. You also learned that the periodic table is organized into rows called *periods* (from which the name *periodic table* derives) and columns called *groups*. Groups IA and IIA are the *alkali metals* and *alkaline earth metals*, respectively. The B groups are called the *transition metals*.

Through studying the detailed electron structures of atoms, you have now learned that groups of elements behave similarly because they have similar electron configurations in their valence shells. There are many

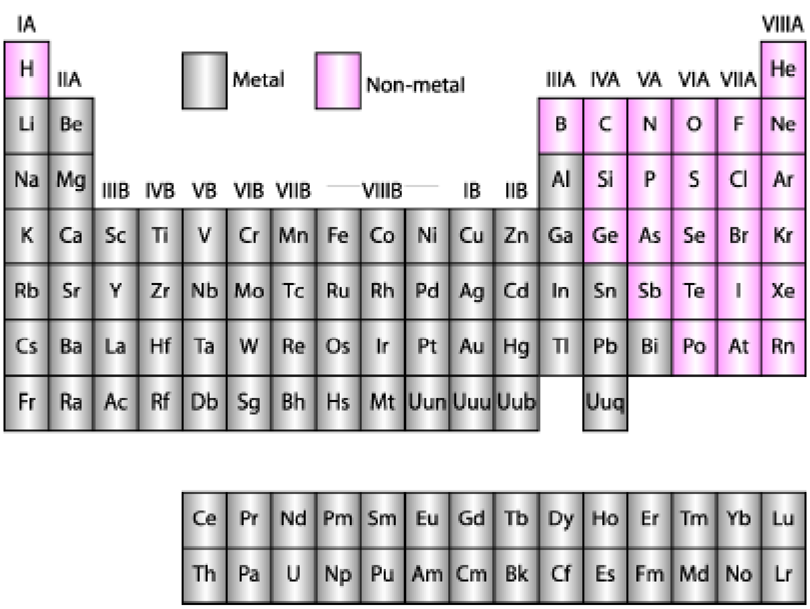

Figure 1. Everything on the left side of the periodic table (that is, with the exception of hydrogen) and a few of the post-transition elements are met-

ways in which these grouped elements act alike, but for right now we want to focus on only one of those. All the elements in group IA, the alkali metals, behave similarly in terms of the *kinds of ions they form*. It is easy for each of these elements to lose an electron and form a 1+ cation, because they all have a single electron in a half-empty *s* orbital. When any of these elements forms an ion, it will be a 1+ cation. Hydrogen is not a metal, but it can behave in the same way as every metal in this group. This should be pretty easy to remember—group IA elements form 1+ cations.

Now look at group IIA. The elements in IIA (the alkaline earth metals) all two electrons in their valence shells. (Their *s* sublevels are full.) When they form ions, both of those *s* electrons go away at the same time leaving them with 2+ charges. They always form 2+ cations.

The next group to look at is group IIIA. Yes, I know it's not the next column of elements on the periodic table. The next 10 groups, going left to right, after group IIA are the transition elements, and are given "B" designations. Don't worry about them right now. group IIIA is the first group after the transition elements—you might call them post-transition elements. Again, boron (like hydrogen) is actually a nonmetal, but it behaves the same way as the metals in the group. What kind of ion do you suppose group IIIA elements form? Right, 3+ cations. To summarize then, each of the groups IA to IIIA form the cations that correspond to their group numbers: group IA elements form 1+ ions, group IIA elements form 2+ ions, and group IIIA elements form 3+ ions.

Now move on over to the far right of the periodic table to the noble gases. Remember? Their *s* and *p* sublevels are full. They have eight electrons in their valence shells. The fact is, they just don't tend to form ions at all. They don't even form compounds with other elements very easily. So don't worry about them right now.

Moving one group to the left of the noble gases, we find group VIIA—the halogens. Notice that these are all nonmetals. These elements are alike in the way they form ions. It is easy for each of these elements to gain an electron and form a 1– anion, thereby filling their valence shells with eight electrons.

Now move another group to the left to group VIA. These elements all form 2– anions. And you can probably guess what kind of ions are formed by the elements in group VA. Right, 3– anions. Please remember these tendencies: Groups IA, IIA, and IIIA form 1+, 2+, and 3+ ions, respectively. Groups VIIA, VIA and VA form 1–, 2– and 3– ions, respectively. You'll need this information to name compounds properly.

Type I Binary Compounds

The first question to ask when you are given a binary compound to name is: "Does this compound contain a metal?" (See Figure 1.) If the answer is "No", then you'll have to wait a few days to learn how to name it. But if the answer is "Yes", then the next question you want to ask is this: "Does the metal in this compound form only one kind of cation?" If the answer is "No", then you'll have to wait a few days to name it. But if the answer is "Yes", then you have what is called a "Type I" binary compound, and by the end of today's lesson you'll know exactly what to call it. Then you can communicate the name of that compound to any other person in the world who knows the language of chemistry.

Of course, you may want to know how to tell if the metal in your compound can form more than one kind of cation. Here's how you tell: does it belong to group IA, IIA or IIIA? If so, then it can form only one kind of cation. The other common metals that can form only one kind of cation are Ni (2+), Zn (2+), Ag (1+) and Cd (2+). (See Figure 2.) You'll just have to remember these. There are some other, less common ones that show up on the Figure, but chemists run across these so infrequently that you needn't bother memorizing them.

Once you have established that the binary compound you are trying to name contains a metal that can form only one kind of cation, then you already have half the name. The name will always begin simply with the name of the metal. The second part of the name will be related to the nonmetal with which the metal

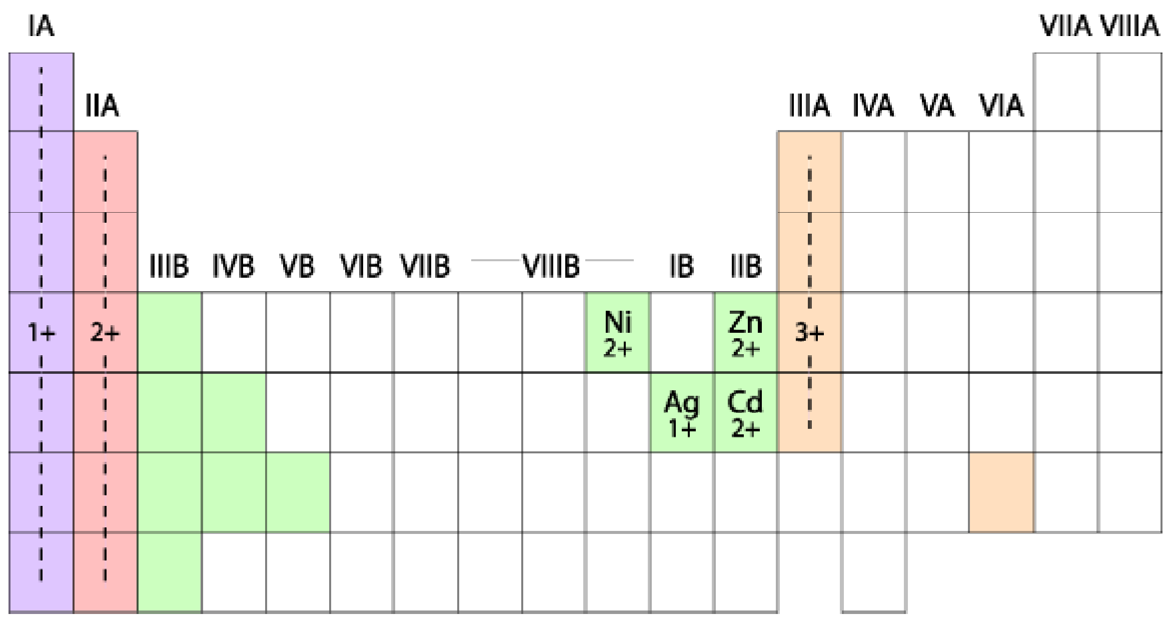

Figure 2. These are the elements that form only one kind of cation. However, if you just remember Groups IA (1+), IIA (2+), IIIA (3+), Ni, Zn and Cd (2+) and Ag (1+), you'll probably never run across a need for any of the others.

reacts. Whatever that element is, you take the stem of that element's name and add the ending "ide." A listing of the stems of some common nonmetals is given in the Table.

As I said once before, when hydrogen forms a cation, its charge is always 1+. However, it can also be the nonmetal component of a binary compound—it can also form an anion with a 1– charge. That's why it sometimes appears in two places on a periodic table. It appears in group IA (with other elements that form 1+ ions) and in group VIIA (with other compounds that form 1– ions).

Now you have all the information you need to name a *lot* of compounds. Let's work our way through the naming of some. Just remember that we are covering only Type I compounds so far, so each will contain one of the metals from Figure 2 that forms only one type of cation and one of the nonmetals (Figure 1) that forms an anion.

Your first mission is to name the compound that has the formula $CaCl_2$. First, let's confirm that it is the correct type of compound:

Table. Stems that represent common nonmetals in the naming of compounds.

Element Name	Element Symbol	Stem + "ide"
hydrogen	H	hydride
carbon	C	carbide
nitrogen	N	nitride
oxygen	O	oxide
fluorine	F	fluoride
phosphorus	P	phosphide
sulfur	S	sulfide
chlorine	Cl	chloride
selenium	Se	selenide
bromine	Br	bromide
iodine	I	iodide

1) Is it binary? That is, does it consist of only two elements? Yes, it consists of only calcium and chlorine.
2) Does the compound contain a metal? Yes, according to Figure 1 its metal is calcium.
3) Does the metal form only one kind of cation? Yes, it's a group IIA metal. Those metals form only 2+ ions.

We can confidently conclude that we are naming a Type I binary compound.

Second, let's name it:

1) The first part of the name is *calcium*.
2) The second part of the name is *chloride*.

Third, put it all together.

The name of the compound is *calcium chloride*.

Instead of going through this process in your mind every time, you should learn to name compounds quickly at a glance. Let's name each of the following Type I binary compounds. (Cover up the names I provided and see if you can name them on your own. Check them first to be sure they are all Type I binary compounds. We wouldn't want to be fooled by one, now would we?):

1)	LiH	lithium hydride
2)	$SrBr_2$	strontium bromide
3)	Na_2O	sodium oxide
4)	AlI_3	aluminum iodide
5)	$CuCl_2$	copper chloride
6)	Mg_3N_2	magnesium nitride

Notice that if you don't know which elements are metals and which carry only one kind of charge, you'll never quite know whether you have named the compound properly. Take compound number 5 for instance. If you didn't check carefully, you overlooked the fact that copper is in one of the B groups. It forms more than one type of cation. This compound is improperly named. I hope you caught it! If you didn't, pinch yourself. If you did, give yourself a hug. I'm sorry I can't be there to see it. (As you'll find out in the next lesson, if the metal forms more than one type of cation, you'll have to specify how many atoms are present. At that point you'll learn how to properly name copper chloride.)

Writing the Formulas of Type I Compounds

You may have noticed that the elements making up binary compounds don't always combine in one-to-one ratios. For example, the formula for magnesium nitride is Mg_3N_2. Why is that? If you think about it, it's exactly what you would expect. Remember, magnesium is a group IIA element and therefore forms 2+ ions. Nitrogen is a group VA element and forms 3– ions. So in order for magnesium and nitrogen to combine and produce a neutral compound, there must be 3 magnesium cations (with a total charge of +6) and 2 nitrogen anions (with a total charge of –6). Once we understand this principle, if we are given the name of a Type I binary compound, we can figure out what the formula *must* be.

Let's try a few. What would be the formula for calcium sulfide? Write the symbol for the metal and lightly pencil its charge above it, like this:

$$\overset{2+}{\text{Ca}}$$

Remember, for a Type 1 compound there must be only one possibility. Now we need enough sulfur atoms to neutralize a 2+ charge. Sulfur is in group VIA and forms a 2– anion. Write it:

$$\overset{2+}{\text{Ca}}\ \overset{2-}{\text{S}}$$

The charges are balanced, so we are finished. The formula will simply be CaS.

That was much too easy. Let's do one that requires you to be awake. What would be the formula for calcium fluoride? Write the metal and its charge, then the nonmetal and its charge. Calcium is in group IIA (2+), while fluorine is in VIIA (1–):

2+ 1–

$$\mathrm{Ca}\quad \mathrm{F}$$

Obviously we need two fluorine atoms to balance the charge of calcium:

$$\begin{matrix} 2+ & 2(1-) \\ \mathrm{Ca} & \mathrm{F}_2 \end{matrix}$$

Now the charges are balanced. The formula will be:

$$CaF_2$$

This last example is as tough as it gets. If you can do this you've got it licked. What would be the formula for calcium phosphide?

$$\begin{matrix} 2+ & 3- \\ \mathrm{Ca} & \mathrm{P} \end{matrix}$$

Since charges of 2+ and 3– do not balance, the lowest common multiple of 2 and 3 is 6. We now need to balance a charge of 6+ with a charge of 6–. Since calcium has a charge of 2+, show 3 calcium ions to give it a total charge of 6+. Likewise, since phosphorus has a charge of 3–, show 2 phosphorus ions to give it a total charge of 6–.

$$\begin{matrix} 3(2+) & 2(3-) \\ \mathrm{Ca}_3 & \mathrm{P}_2 \end{matrix}$$

The charges on the three calcium ions [3(2+), or 6+] and the two phosphorus ions [2(3–), or 6–] are now balanced:

$$\begin{matrix} 6+ & 6- \\ 3(2+) & 2(3-) \\ \mathrm{Ca}_3 & \mathrm{P}_2 \end{matrix}$$

The formula is Ca_3P_2. Now you do some.

Exercises

1) Name the following Type I binary compounds:

   a) Li_3N
   b) $AlCl_3$
   c) CaH_2
   d) BaO
   e) K_2S

2) Write the formulas for the following Type I binary compounds:

   a) zinc chloride
   b) silver oxide
   c) magnesium bromide
   d) aluminum oxide
   e) lithium iodide