3.7: Naming Ionic Compounds

Sometimes, it is useful to be able to recognize the name of a compound and know how to translate it into the structure. You might need to go the other direction, too; if you see a formula -- the ratio of atoms in a compound -- you may want to be able to name the compound.

Take a common ionic compound such as table salt or rock salt, which has the formula NaCl. To name this compound systematically, we just name the two ions of which it is composed: sodium and chlorine. We leave the name of the cation exactly as it is in the periodic table, but we change the ending of the anion's name to *-ide*. We name the cation first and the anion second.

- Name the cation first and the anion second.
- Change the ending of the anion to *-ide*.

In this case, sodium is the cation and chlorine is the anion, so the name for NaCl is sodium chloride.\

How did we know which one was the cation and which was the anion? For one thing, when we write the formula of a simple ionic compound, we usually writethe elements in the same order: cation before anion. If you didn't know that, or if for some reason the formula did not appear in that order, you should still be able to work it out based on the layout of the periodic table. The key is usually found in the elements that form the first two columns of the periodic table. These are the alkali and alkaline earth metals. They are very commonly found in ionic compounds, and they are reliably found as cations in those compounds.

The alkali metals are always found as 1+ or monovalent cations, such as Na^+, K^+, or Li^+. The reason, of course, is that these metals all have one electron in a shell that has been newly started; that shell is far from the nucleus, so the electron is ot held very tightly and it is lost pretty easily.

A similar thing is true for the alkaline earth metals such as magnesium or calcium. These metals have two electrons in the outermost shell, and there still are not enough protons in that distant nucleus to hold those electrons tightly. As a result, both of these electrons are easily lost, and so magnesium is most often found as Mg^{2+} and calcium is usually found as Ca^{2+}.

Once you have identified the cation, you can quickly decide that the other atom in the formula must be the anion.

? Exercise 3.7.1

Provide formulae for the following names.

a) lithium fluoride b) sodium iodide c) potassium bromide d) magnesium chloride

e) calcium oxide f) beryllium sulfide g) sodium oxide h) lithium nitride

Answer a:

LiF

Answer b:

NaI

Answer c:

KBr

Answer d:

$MgCl_2$

Answer e:

CaO

Answer f:

BeS

Answer g:

Na_2O

Answer h:

Li_3N

A similar line of reasoning works with atoms on the other side of the periodic table. Halogens, such as fluorine and chlorine, are frequently found as halide ions, such as fluoride, F-, and chloride, Cl-. However, the halogens and other elements toward the right hand side of the periodic table display a little more versatility that the alkali and alkaline earth metals. Consequently, if you spot chlorine or oxygen in a structure, you can't always be sure it is acting as a simple anion.

For example, there are host of compounds that are "polyatomic ions", clusters of atoms bound tightly together that have an overall charge. Many of these ions contain oxygen. Although oxygen does exist as a simple oxide anion, O^{2-}, that isn't the case in these examples. Because the oxoanions are very common, they have their own names. That lets us distinguish chloride, Cl^-, and oxide, O^{2-}, from chlorate, ClO_3^-. Some of the most common oxoanions are found in the table below.

Most Common Oxoanions

series	lowest # oxygens			highest # oxygens
chlorine	hypochlorite, ClO^-	chlorite, ClO_2^-	chlorate, ClO_3^-	perchlorate, ClO_4^-
sulfur		sulfite, SO_3^{2-}	sulfate, SO_4^{2-}	persulfate, SO_5^{2-}
phosphorus	hypophosphite, $H_2PO_2^-$	phosphite, HPO_3^{2-}	phosphate, PO_4^{3-}	
nitrogen		nitrite, NO_2^-	nitrate, NO_3^-	

All of these anions have oxygen atoms bound to a central atom of another kind. For example, in chlorate, four oxygen atoms are attached to a central chlorine atom. (The only exception, and it probably isn't important at this point, is persulfate; it has four oxygen atoms attached to a central sulfur atom, and the fifth oxygen hangs from one of the other oxygen atoms.) The names of each of these ions seem a little random until you consider them together. Then, it becomes clear that the names offer clues to the structure. The ending -*ate* always means more oxygens than -*ite*, although neither one corresponds to a specific number of oxygen atoms. The prefix *per*- always means an extra oxygen (beyond what we see in the -*ate* ion), whereas the prefix *hypo*- means even fewer oxygens than in the -*ite* ion.

However, none of those names would signal to us that hydrogen atoms are also attached to the central atom, in addition to the oxygens, but that's what we have in phosphite and hypophosphite.

In addition to these examples, there are a few carbon-based oxoanions that are pretty common: carbonate (CO_3^{2-}), formate (HCO_2^-) and acetate ($CH_3CO_2^-$). Like some of the phosphorus examples, the last two are rather complicated, with hydrogens attached to the central carbons as well as the oxygens seen in all the other cases.

There are also a few polyatomic cations, but they aren't as common as these anions. The most prevalent one in ammonium, NH_4^+.

? Exercise 3.7.2

Provide formulae for the following names.

a) sodium nitrate b) potassium perchlorate c) lithium sulfate

d) ammonium phosphate e) magnesium carbonate f) calcium hypochlorite

g) sodium acetate h) beryllium chlorate

Answer a:

$NaNO_3$

Answer b:

$KClO_4$

Answer c:

Li_2SO_4

Answer d:

$(NH_4)_3PO_4$

Answer e:

$MgCO_3$

Answer f:

$Ca(OCl)_2$

Answer g:

NaO_2CCH_3

Answer h:

$Be(ClO_3)_2$

Towards the middle of the periodic table, it becomes a lot harder to predict the charges on cations. It's not like in those first few columns, where if something is from the first column, its charge is 1+, and if it is from the second column, its charge is 2+. What if a metal comes from the seventh column in the periodic table? Is it guaranteed to be a 7+ cation? Not exactly, because that is an awful lot of electrons to lose. In the middle portion of the periodic table, the transition metals, charges can vary from one case to another, and the same metal could be found with different charges in different compounds. One of the familiar examples if iron, which can most commonly be found as a ferric ion, Fe^{3+}, or as a ferrous ion, Fe^{2+} (although other charges are also possible).

To help sort that problem, the charge on these cations is often given in the name. For example, we might refer to iron (III) chloride, $FeCl_3$, vs. iron (II) chloride, $FeCl_2$ (in addition to the common names ferric chloride and ferrous chloride, respectively). The Roman numeral tells you about the positive charge on the cation.

Arabic numeral to Roman numeral Conversion Table

Arabic numeral	Roman numeral
1	I
2	II
3	III
4	IV
5	V
6	VI
7	VII
8	VIII

? Exercise 3.7.3

Provide formulae for the following names.

a) tantalum (V) chloride b) chromium (III) fluoride c) lead (II) bromide

d) mercury (II) chloride e) tungsten (VI) oxide f) molybdenum (IV) sulfide

Answer a:

$TaCl_5$

Answer b:

CrF_3

Answer c:

$PbBr_2$

Answer d:

$HgCl_2$

Answer e:

WO_3

Answer f:

MoS_2

Exercise 3.7.4

Provide names for the following formulae.

a) $LiCl$ b) Na_2S c) LiO_2CCH_3 d) $Mg(NO_2)_2$ e) $Na_2(SO_3)_2$

f) $PbSO_4$ g) OsO_4 h) $Pb(NO_3)_4$

Answer a:

lithium chloride

Answer b:

sodium sulfide

Answer c:

lithium acetate

Answer d:

magnesium nitrite

Answer e:

sodium sulfite

Answer f:

lead (II) sulfate

Answer g:

osmium (VIII) oxide

Answer h:

lead (IV) nitrate