

Welcome!

This is a chemistry lesson, covering *how to name ionic compounds containing certain polyatomic ions* (other than the oxyanions we've already covered in the [previous lesson](#)).

I will guide you step-by-step.

I will be asking you many questions along the way.

Each time I ask a question, **you should attempt to answer the question on your own** before you scroll down to view my answer.

This is a lesson in the chapter “Atoms, Molecules, and Compounds”, which is part of the series “Chemistry, Explained Step by Step”.

This lesson builds on the material covered in the previous lessons:

[Naming Ionic Compounds](#)

[Writing Formulas for Ionic Compounds](#)

[Writing Formulas for Ionic Compounds with Transition Metals](#)

[Naming Ionic Compounds with Transition Metals](#)

[Ionic Compounds with Oxyanions: Names and Formulas](#)

You should complete those lessons before attempting this lesson.

This lesson was written by Freelance-Teacher.

My website is:

<http://www.freelance-teacher.com>

You can support this project with a monthly pledge at my Patreon page:

<https://www.patreon.com/freelanceteacher>

Or you can make a one-time donation using the PayPal Donate link at [my website](#).

I have videos available for many topics in chemistry, and other subjects, at my YouTube channel:

<https://www.youtube.com/@freelanceteach>

You can find a list of all the available lessons, in suggested order, at [my website](#).

You can find links to AI-enhanced versions of all the lessons, which allow you to ask questions, and which can generate additional practice problems, at [my website](#).

You can find a list of all the available videos, in suggested order, at [my website](#).

I offer **tutoring** in chemistry, and a variety of other subjects.

For more information, go to [my website](#).

In the [previous lesson](#),
we discussed how to name ionic compounds containing certain oxyanions.

Here are some other polyatomic anions you may encounter:

acetate: $\text{C}_2\text{H}_3\text{O}_2^-$, or CH_3COO^-

cyanide: CN^-

dichromate: $\text{Cr}_2\text{O}_7^{2-}$

hydrogen carbonate, or “bicarbonate”: HCO_3^-

hydroxide: OH^- , or HO^-

permanganate: MnO_4^-

Notice that the names of the oxyanions in this list (acetate, permanganate, dichromate, bicarbonate) end in -ate.

The names of the other anions (cyanide, hydroxide) end in -ide, like monatomic anions.

(Hydroxide is not considered an “oxyanion”
because it does not contain a “central” atom that the oxygen is bonded to.)

For the time being, I suggest you memorize the names, formulas, and net charges for:
hydroxide (OH^-), and
cyanide (CN^-)

1. Write the name for the compound represented by the formula $\text{Co}(\text{OH})_3$.

Answer:

The name of $\text{Co}(\text{OH})_3$ is *cobalt(III) hydroxide*.

Analysis:

The first step is to identify whether $\text{Co}(\text{OH})_3$ is an ionic compound or a covalent compound.

$\text{Co}(\text{OH})_3$ contains a metal (cobalt) and two nonmetals (oxygen and hydrogen), so $\text{Co}(\text{OH})_3$ is an ionic compound.

Therefore, $\text{Co}(\text{OH})_3$ is composed of ions.

You should have memorized that

cobalt can form two different cations with two different charges.

Before we can name $\text{Co}(\text{OH})_3$,

we need to figure out the charge on the cobalt ion.

The formula $\text{Co}(\text{OH})_3$ indicates that one formula unit contains
a single cobalt cation, and
three hydroxide anions.

For clarity, in the notation below let's explicitly write the subscript ₁ for the cobalt cation.

We just memorized that the individual charge on each hydroxide anion is -1.

So the "group" of three hydroxide anions has a total charge of $3(-1) = -3$.

group charges		-3
	Co_1	$(\text{OH})_3$
individual charges	?	-1

We know that $\text{Co}(\text{OH})_3$ has a net charge of zero.

In order for the net charge to be zero,

the "group" of one cobalt cation must have a group charge of +3.

That means the individual charge on the single cobalt cation must also be +3.

group charges	+3	-3
	Co_1	$(\text{OH})_3$
individual charges	+3	-1

group charges	+3	-3
	Co ₁	(OH) ₃
individual charges	+3	-1

Our goal was to determine the individual charge on the cobalt ion.
We have achieved that goal: the cobalt has a +3 charge.

Therefore, the name of Co(OH)₃ is *cobalt(III) hydroxide*.

2. What is the chemical formula for magnesium cyanide?

Answer:

The chemical formula for magnesium cyanide is $\text{Mg}(\text{CN})_2$.

Analysis:

First, we check whether we are dealing with an ionic or a covalent compound.

$\text{Mg}(\text{CN})_2$ contains a metal (magnesium) and two nonmetals (carbon and nitrogen), so $\text{Mg}(\text{CN})_2$ is an ionic compound.

Therefore, $\text{Mg}(\text{CN})_2$ is composed of ions.

When writing the formula for an ionic compound, it is *your job* to figure out the subscripts.

For clarity, in the notation below we will write the cyanide ion inside parentheses.

We know that the charge on each individual magnesium cation is +2.

We just memorized that the charge on each individual cyanide anion is -1.

group charges		
	Mg	(CN)
individual charges	+2	-1

Now, we have to choose subscripts that will result in a compound with a net charge of zero.

Let's *guess* that the correct subscripts

are ₁ for the magnesium ion and ₂ for the cyanide ion.

Now we need to *check* whether those subscripts result in a net charge of zero.

According to our guess,

the “group” of one magnesium ion would have a charge of $1(+2) = +2$;

and the group of two cyanide ions would have a charge of $2(-1) = -2$.

group charges	+2	-2
	Mg_1	$(\text{CN})_2$
individual charges	+2	-1

net charge = $+2 + (-2)$

So, net charge = 0.

That was the outcome we were hoping for.

So we conclude that ₁ and ₂ are the *correct* subscripts.

Our answer is that the chemical formula for magnesium cyanide is $\text{Mg}(\text{CN})_2$.

All of the polyatomic ions we have discussed so far in these lessons have been polyatomic anions.

Now we will introduce a polyatomic cation:
ammonium ion, NH_4^+

This ion could also be referred to as “ammonium cation”, or simply as “ammonium”.

You should memorize the name, formula, and net charge for this polyatomic cation.

3. What is the rule for determining whether a compound is ionic or covalent?

As we have learned in previous lessons, the rule is:

If a compound consists of a metal and one or more nonmetals,
then the compound is probably *ionic*.

If a compound consists of nonmetals only,
then the compound is *covalent*.

Now, we will learn an exception to these rules.

Exception:

Compounds containing ammonium are *ionic*,
even though they generally consist of nonmetals only.

For example,
 NH_4Cl contains ammonium,
so NH_4Cl is an ionic compound,
even though it consists of nonmetals only.

For another example,
 NH_4ClO_3 contains ammonium,
so NH_4ClO_3 is an ionic compound,
even though it consists of nonmetals only.

4. What is the name for $(\text{NH}_4)_2\text{O}$?

Answer:

The name of $(\text{NH}_4)_2\text{O}$ is ammonium oxide.

Analysis:

The first step is to identify whether $(\text{NH}_4)_2\text{O}$ is an ionic compound or a covalent compound.

We have memorized that compounds containing ammonium are ionic, even though they consist of nonmetals only.

So $(\text{NH}_4)_2\text{O}$ is an ionic compound.

So $(\text{NH}_4)_2\text{O}$ is composed of ions.

One formula unit of $(\text{NH}_4)_2\text{O}$ contains two NH_4^+ cations, and one O^{2-} anion.

We are ready to apply the rules for naming ionic compounds.

The name of the compound $(\text{NH}_4)_2\text{O}$ is ammonium oxide.

Notice that:

The name of the cation (ammonium ion) appears first, but without the word “ion”.

The name of the anion (oxide ion) appears second, but without the word “ion”.

We have memorized the name for this polyatomic cation: ammonium.

The name of the monatomic anion (oxide) is adapted from the name of the element (oxygen), but with an -ide suffix.

The subscripts ₂ and ₁ from the formula do not affect the name of the ionic compound.

5. What is the chemical formula for ammonium phosphate?

Answer:

The chemical formula for ammonium phosphate is $(\text{NH}_4)_3\text{PO}_4$.

Analysis:

First, we check whether we are dealing with an ionic or a covalent compound.

We have memorized that compounds containing ammonium are ionic, even though they consist of nonmetals only.

So $(\text{NH}_4)_3\text{PO}_4$ is an ionic compound.

When writing the formula for an ionic compound, it is *your job* to figure out the subscripts.

We have memorized that the charge on each individual ammonium cation is +1.

We have also memorized that the charge on each individual phosphate anion is -3.

Now, we have to choose subscripts that will result in a compound with a net charge of zero.

Let's *guess* that the correct subscripts

are ₃ for the ammonium ion and ₁ for the phosphate ion.

For clarity, in our notation below we write the phosphate ion inside parentheses, and explicitly show the subscript of ₁

group charges		
	$(\text{NH}_4)_3$	$(\text{PO}_4)_1$
individual charges	+1	-3

Now we need to *check* whether those subscripts result in a net charge of zero.

According to our guess,

the group of three ammonium ions would have a charge of $3(+1) = +3$;

and the group of one phosphate ion would have a charge of $1(-3) = -3$.

group charges		
	+3	-3
	$(\text{NH}_4)_3$	$(\text{PO}_4)_1$
individual charges	+1	-3

group charges	+3	-3
	(NH ₄) ₃	(PO ₄) ₁
individual charges	+1	-3

net charge = +3 + (-3)

So, net charge = 0.

That was the outcome we were hoping for.

So we conclude that ₃ and ₁ are the *correct* subscripts.

The convention is that subscripts of ₁ are omitted from the chemical formula.

Furthermore, the convention is that, when a formula unit contains only one “copy” of a polyatomic ion, the parentheses around the polyatomic ion are omitted from the formula.

So our answer is that the chemical formula for ammonium phosphate is (NH₄)₃PO₄.

Let's review the material from this lesson.

6. What are polyatomic anions?

What are polyatomic cations?

What are oxyanions?

A polyatomic anion is a *group* of atoms with a *negative* charge.

A polyatomic cation is a group of atoms with a positive charge.

An oxyanion is:

a *polyatomic anion*

containing one or more *oxygen* atoms

covalently bonded to a central atom.

7. What are the two polyatomic anions that are not oxyanions that I have suggested you should memorize?

Give names, formulas, and net charges.

In this lesson I suggested you should memorize these polyatomic anions:

hydroxide, HO^- ; and

cyanide, CN^- .

(Hydroxide is not considered an "oxyanion"

because it does not contain a "central" atom that the oxygen is bonded to.)

Your professor may require you to memorize some other polyatomic anions as well, such as:

acetate: $\text{C}_2\text{H}_3\text{O}_2^-$, or CH_3COO^-

dichromate: $\text{Cr}_2\text{O}_7^{2-}$

hydrogen carbonate, or "bicarbonate": HCO_3^-

permanganate: MnO_4^-

**8. What is the one polyatomic cation that is likely to be important in this chapter?
Give the name, formula, and net charge.**

In this chapter, the only polyatomic cation that is likely to be important is:
ammonium, NH_4^+

**9. What is the structure of ammonium?
Go into as much detail as possible.**

Ammonium (NH_4^+) is a polyatomic **cation**, composed of
one nitrogen atom, and
four hydrogen atoms.

Ammonium is composed of nonmetals only.
Therefore, the ion is held together by *covalent bonds* between the atoms.

The net charge of the ion is +1.
Notice that this +1 net charge refers to the *entire ion as a whole*,
not just to the hydrogen atoms.

10. True or false. Explain why the statement is true or false.
The formula for ammonium oxide is NH_4O .

False.

Ammonium oxide is an *ionic compound*.

When writing the formula for an ionic compound, it is your job to determine the correct subscripts for the formula.

Each ammonium ion (NH_4^+) carries a +1 charge.
The oxide ion (O^{2-}) carries a -2 charge.

In order to balance the -2 charge from the oxide ion,
we need *two* ammonium ions (each +1), to achieve a net charge of zero.

So the correct formula is $(\text{NH}_4)_2\text{O}$.

11. True or false. Explain why the statement is true or false.
The name for the compound CuCN is copper cyanide.

False.

You should have memorized that copper is an element whose cation can take two different charges.
Therefore, the name copper cyanide is inadequate because it does not indicate the charge on the copper cation.

The cyanide ion (CN^-) has a -1 charge.
Since there is one CN^- ion in the formula, the copper cation must have a +1 charge to balance it.

So the correct name for CuCN is *copper(I) cyanide*.

You have reached the end of the lesson.

You're ready now to proceed to the next lesson:

[Names and Formulas for Covalent Compounds](#)