

Welcome!

This is a chemistry lesson, covering *how to tell whether a chemical formula represents an ionic compound or a covalent compound*.

This lesson also introduces the topic of *polyatomic anions*.

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 we covered in the previous lessons on [Ions](#), and [Ionic Compounds and Covalent Compounds](#).

You should complete those lessons before proceeding with this lesson.

The script for this lesson was written by Freelance-Teacher.

My website is:

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

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Please take a look at your periodic table.

Most of the elements in the periodic table can be divided into *metals* and *nonmetals*.

The metals are located towards the *left* of the periodic table.

The nonmetals are located towards the *right* of the periodic table.

Exception: hydrogen (H) is a nonmetal, even though it's on the left of the periodic table.

There is a zig-zag diagonal line that separates the metals from the nonmetals in the periodic table.

(The elements right next to that line are referred to as “metalloids” or “semimetals”).

You can find a periodic table that clearly indicates the zig-zag diagonal line between the metals and the nonmetals at this link:

[https://chem.libretexts.org/Courses/Heartland Community College/HCC%3A Chem 161/2%3A Atoms Molecules and Ions/2.5%3A The Periodic Table#:~:text=Metals%20are%20located%20on%20the,a%20diagonal%20band%20of%20semimetals](https://chem.libretexts.org/Courses/Heartland_Community_College/HCC%3A_Chem_161/2%3A_Atoms_Molecules_and_Ions/2.5%3A_The_Periodic_Table#:~:text=Metals%20are%20located%20on%20the,a%20diagonal%20band%20of%20semimetals)

For example:

1. Is calcium a metal or a nonmetal?

Calcium (Ca) is on the left of the periodic table.

So calcium is a metal.

If you haven't memorized the symbols for common elements like calcium yet, you should go back and work through the lesson on [Atoms, Protons, Neutrons, and Electrons](#).

2. Is oxygen a nonmetal or a metal?

Oxygen (O) is on the right of the periodic table.

So oxygen is a nonmetal.

3. Is aluminum a nonmetal or a metal?

Aluminum (Al) is to the left of the diagonal line in the periodic table, so aluminum is a *metal*.

You can confirm this by checking that aluminum is to the left of the diagonal line in the periodic table at [this link](#).

Of course, even without looking at the periodic table, you should already have known from your own everyday knowledge that aluminum is a metal.

4. Is carbon a nonmetal or a metal?

Carbon (C) is to the right of the diagonal line in the periodic table, so carbon is a *nonmetal*.

5. Is hydrogen a nonmetal or a metal?

Hydrogen (H) is on the left of the periodic table, but we have learned that hydrogen is an *exception* to the general pattern for finding metals and nonmetals.

You need to memorize that hydrogen is a *nonmetal*, even though it's on the left of the periodic table.

Please confirm that hydrogen is color-coded as a *nonmetal* in the periodic table at [this link](#).

Of course, even without learning about the “exception” or looking at the periodic table, you should already have known from your own store of everyday knowledge that hydrogen is a nonmetal.

Hydrogen is commonly encountered as a gas, and you should already know, from your own everyday knowledge, that gases are not metals.

6. Is iodine a metal or a nonmetal?

Iodine (I) is to the right of the diagonal line in the periodic table.

So iodine is a nonmetal.

7. Is tin (Sn) a metal or a nonmetal?

Tin (Sn) is to the left of the diagonal line in the periodic table.

So tin is a metal.

Your everyday knowledge should confirm that tin is a metal.

8. Is lithium a metal or a nonmetal?

Lithium (Li) is to the left of the diagonal line in the periodic table.

So lithium is a metal.

The basic chemical difference between metals and nonmetals is that,
when forming ionic compounds,
metals tend to *lose* electrons to become cations
and nonmetals tend to *gain* electrons to become anions.

To review:

9. Where are the metals located in the periodic table?

Where are the nonmetals located in the periodic table?

The metals are located towards the left of the periodic table.

The nonmetals are located towards the right of the periodic table.

Exception: hydrogen (H) is a nonmetal, even though it's on the left of the periodic table.

The diagonal boundary between metals and nonmetals is indicated on some versions of the periodic table.

10. What is the basic chemical difference between metals and nonmetals?

The basic chemical difference between metals and nonmetals is that, when forming ionic compounds, metals tend to *lose* electrons to become cations and nonmetals tend to *gain* electrons to become anions.

Now, how can you tell from a chemical formula whether the formula represents an ionic compound or a covalent compound?

If the formula contains a metal and a nonmetal, it usually represents an *ionic* compound.

If the formula contains only nonmetals, it usually represents a *covalent* compound.

For example:

11. Is CaCl_2 an ionic compound or a covalent compound?

Calcium (Ca), on the left of the periodic table, is a metal.

Chlorine (Cl), on the right of the periodic table, is a nonmetal.

Since the formula contains a metal and a nonmetal,
we conclude that CaCl_2 represents an *ionic* compound.

12. Is CO_2 an ionic compound or a covalent compound?

Carbon (C), on the right of the periodic table, is a nonmetal.

Oxygen (O), on the right of the periodic table, is a nonmetal.

Since the formula contains only nonmetals,
we conclude that CO_2 represents a *covalent* compound.

13. Is N_2 a covalent substance or an ionic substance?

Nitrogen (N), on the right of the periodic table, is a nonmetal.

Since the formula contains only a nonmetal,
we conclude that N_2 represents a *covalent* substance.

(A *compound* is defined as a combination of *different* elements,
and N_2 consists of only one element, nitrogen;
so nitrogen is referred to as a covalent *substance*, not as a covalent *compound*.
But that distinction probably will not be important in your course.)

14. Is K_2O a covalent compound or an ionic compound?

Potassium (K), on the left of the periodic table, is a metal.

Oxygen (O), on the right of the periodic table, is a nonmetal.

Since the formula contains a metal and a nonmetal,
we conclude that K_2O represents an *ionic* compound.

**15. Acetic acid, formula $C_2H_4O_2$, is a key component of vinegar.
Is acetic acid a covalent compound or an ionic compound?**

Carbon (C), on the right of the periodic table, is a nonmetal.

Oxygen (O), on the right of the periodic table, is a nonmetal.

We have memorized that hydrogen (H) is a nonmetal, even though it's on the left of the table.
Since the formula contains only nonmetals,
we conclude that $C_2H_4O_2$ represents a *covalent* compound.

16. Is $NaNO_3$ a covalent compound or an ionic compound?

Sodium (Na), on the left of the periodic table, is a metal.

Nitrogen (N) and oxygen (O), on the right of the periodic table, are nonmetals.

Since the formula contains both a metal and nonmetals,
we conclude that $NaNO_3$ represents an *ionic* compound.

We have discussed how to distinguish ionic compounds from covalent compounds.

Now we will move on to our next topic: polyatomic ions.

17. What is an ion?

An *ion* is defined as:
an atom or group of atoms
with a positive or negative electric charge.

A *single* atom with an electric charge is called a *monatomic* ion.

A *group* of atoms with an electric charge is called a *polyatomic* ion.

(“Mono-” is from the Greek word for “one”; “poly-” is from the Greek word for “many”.)

So far in these lessons, we have discussed monatomic ions;
for example, Na^+ , Mg^{2+} , Al^{3+} , P^{3-} , S^{2-} , Cl^- .

Now we will discuss *polyatomic* ions.

Here are some examples of polyatomic ions:

ClO^- , ClO_2^- , ClO_3^- , ClO_4^- ,

H_2PO_4^- , HPO_4^{2-} , PO_4^{3-} ,

CN^- , HO^- ,

NH_4^+

The only polyatomic *cation* you are likely to deal with in this chapter is NH_4^+ ;
all the other polyatomic ions you will see in this chapter are likely to be polyatomic *anions*.

All the examples of polyatomic ions we will deal with in this chapter are composed of nonmetals only.
(Confirm that this is consistent with the examples above.)

Therefore, for each polyatomic ion we will deal with in this chapter, the atoms in the polyatomic ion are joined by *covalent bonds* (much as the atoms in a neutral molecule are joined by covalent bonds).

Therefore, each polyatomic ion is a group of atoms which are held together by covalent bonds between the atoms; and which collectively have a positive or negative net charge.

The chemical formula for each polyatomic ion includes a superscript which indicates the overall net charge of the *entire group* of atoms.

18. What is the net charge for NH_4^+ ?

The superscript is $^+$.

The superscript $^+$ represents a +1 electric charge.

So the net charge for NH_4^+ is +1.

So NH_4^+ is a polyatomic cation.

Notice that the $^+$ superscript refers to the net charge on the *entire group* of atoms, *not* to a charge on the H's only.

19. What is the net charge for CO_3^{2-} ?

The superscript is $^{2-}$.

So the net charge for CO_3^{2-} is -2.

So CO_3^{2-} is a polyatomic anion.

Notice that the $^{2-}$ superscript refers to the net charge on the *entire group* of atoms, *not* to a charge on the O's only.

20. What is the net charge for Na_2CO_3 ?

Answer: the net charge for Na_2CO_3 is zero.

Analysis:

There is no superscript,
so the net charge for Na_2CO_3 is *zero*.

Therefore, Na_2CO_3 is *not* a polyatomic ion.

(However, Na_2CO_3 does *contain* a polyatomic ion,
namely, CO_3^{2-} , which we discussed in the previous question.)

Na_2CO_3 consists of a metal (Na) and some nonmetals (C and O),
so Na_2CO_3 is an ionic compound.

We will learn more about how to think about complicated ionic compounds like Na_2CO_3 in future lessons;
so don't panic if you don't feel 100% comfortable with them yet.

21. Classify Na_2O as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

Na_2O consists of both a metal (Na) and a nonmetal (O);
so Na_2O represents an *ionic compound*.

22. Classify PH_3 as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

The formula PH_3 consists of nonmetals only,
so we know that the substance with the formula PH_3 is a covalent compound.

Covalent compounds are composed of molecules.
So this covalent compound is composed of molecules with the formula PH_3 .

The formula PH_3 refers to
both the entire *covalent compound*,
and *also* to a single *molecule* of that compound.

23. Classify NO_2^- as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

NO_2^- is a *polyatomic anion*
(a group of atoms with a negative charge).

24. Classify NH_4^+ as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

NH_4^+ is a *polyatomic cation*
(a group of atoms with a positive charge).

25. Classify Ca^{2+} as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

Ca^{2+} is a *monatomic cation*
(a single atom with a positive charge).

26. Classify F^- as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

F^- is a *monatomic anion*
(a single atom with a negative charge).

Let's review what we've learned in this lesson.

**27. Where are the metals located in the periodic table?
Where are the nonmetals located in the periodic table?**

The metals are located towards the left of the periodic table.

The nonmetals are located towards the right of the periodic table.

Exception: hydrogen (H) is a nonmetal, even though it's on the left of the periodic table.

The diagonal boundary between metals and nonmetals is indicated on some versions of the periodic table.

28. What is the basic chemical difference between metals and nonmetals?

The basic chemical difference between metals and nonmetals is that,
when forming ionic compounds,
metals tend to *lose* electrons to become cations
and nonmetals tend to *gain* electrons to become anions.

**29. How can you tell from a chemical formula
whether the formula represents an ionic compound or a covalent compound?**

If the formula contains a metal and a nonmetal,
it usually represents an ionic compound.

If the formula contains only nonmetals,
it usually represents a covalent compound.

(We will encounter one exception to this rule later in this chapter.)

**30. How would you “classify” ClO_2^- ?
Tell me as much as you can about ClO_2^- from the formula.**

ClO_2^- is a group of atoms with a negative charge,
so ClO_2^- is classified as a *polyatomic anion*.

From the chemical formula, we can figure out that:
The ion is held together by covalent bonds between the atoms; and
the net charge on the ion as a whole (not just on the oxygens) is -1.

31. What holds a single ion of ClO_2^- together?

A single ion of ClO_2^- is held together by covalent bonds between the atoms.

In this lesson, we have discussed two types of compounds:
ionic compounds, and
covalent compounds.

In the following lessons, we will learn
how to *name* ionic compounds, and
how to *name* covalent compounds.

In the process, we will gain a better understanding of ionic compounds,
especially of ionic compounds containing polyatomic ions.

Now, I will give you a Review Quiz testing the material we have covered in these lessons: [Ions](#), [Ionic Compounds and Covalent Compounds](#), and Distinguishing Ionic and Covalent Compounds (this lesson)

You should complete those lessons before proceeding with this Review Quiz.

32. What is a covalent bond?

A covalent bond consists of a pair of electrons that is *shared* between two atoms in a molecule.

33. Classify NO_3^- as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

NO_3^- is a polyatomic anion (a group of atoms with a negative charge).

34. What holds a single ion of NO_3^- together?

A single ion of NO_3^- is held together by covalent bonds between the atoms.

**35. What parts are covalent compounds composed of?
What parts are ionic compounds composed of?**

Covalent compounds are composed of molecules.

Ionic compounds are composed of ions.

36. What is an ion?

An ion is defined as
an atom or group of atoms
with a positive or negative electric charge.

(A *single* atom with a positive or negative electric charge is a *monatomic ion*;
a *group of atoms* with a positive or negative electric charge is a *polyatomic ion*.)

37. How can you tell from a chemical formula whether the formula represents an ionic compound or a covalent compound?

If the formula contains a metal and a nonmetal, it usually represents an *ionic* compound.

If the formula contains only nonmetals, it usually represents a *covalent* compound.

**38. Write the symbol for the ion likely to be formed by iodine.
Is it a cation or an anion?**

Answer:
 I^- anion

Analysis:
The closest noble gas to iodine (I) in the periodic table is xenon (Xe).

Xenon is one step to the right of iodine in the table.
Therefore, in order to obtain an electron configuration similar to xenon,
iodine wants to gain one electron,
resulting in an I^- anion.

**39. Write the symbol for the ion likely to be formed by nitrogen.
Is it a cation or an anion?**

Answer:
 N^{3-} anion

Analysis:
The closest noble gas to nitrogen (N) in the periodic table is neon (Ne).

Neon is three steps to the right of nitrogen in the table.
Therefore, in order to obtain an electron configuration similar to neon,
nitrogen wants to gain three electrons,
resulting in an N^{3-} anion.

40. What is the net charge for SO_4^{2-} ?

The superscript is $^{2-}$.

The superscript $^{2-}$ represents a -2 electric charge.

So the net charge for SO_4^{2-} is -2.

(So SO_4^{2-} is a polyatomic anion.)

Keep in mind that the -2 charge applies to the ion as a whole, not to the oxygens only.

41. Classify CO as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

CO consists of nonmetals only, so CO is a covalent compound.

The covalent compound CO is composed of many, many, many separate CO molecules.

So CO is the chemical formula for the entire *covalent compound*,
and CO is *also* the chemical formula for a single *molecule* of that compound.

**42. What is the structure of the compound carbon dioxide gas (CO₂)?
Give as much detail about as many layers of structure as possible.**

CO₂ gas consists of nonmetals only (carbon and oxygen),
so CO₂ gas is a covalent compound.

Therefore, a container of carbon dioxide gas is a collection of many, many, many separate molecules.

Each molecule of carbon dioxide has the chemical formula CO₂,
so each molecule is composed of one carbon atom and two oxygen atoms;
each molecule is held together by covalent bonds between the atoms.

CO₂ is the chemical formula for the entire *covalent compound*, carbon dioxide;
and CO₂ is also the chemical formula for a single *molecule* of carbon dioxide.

**43. Where are the metals located in the periodic table?
Where are the nonmetals located in the periodic table?**

The metals are located towards the left of the periodic table.
The nonmetals are located towards the right of the periodic table.

Exception: hydrogen (H) is a nonmetal, even though it's on the left of the periodic table.

Some periodic tables have a diagonal line showing the boundary between the metals and the nonmetals.

44. What is the difference between how subscripts are interpreted in ionic versus covalent compounds?

In an ionic compound, the subscripts in the chemical formula tell you the *ratio* of elements in the compound.

In a covalent compound, the subscripts tell you the *actual number* of atoms of each element contained in *one molecule* of the compound;
therefore, the subscripts also tell you the ratio of the elements in the *covalent compound as a whole*.

**45. What are molecules composed of?
What holds molecules together?**

Molecules are composed of atoms.

Molecules are held together by *covalent bonds* between the atoms.

46. Classify Fe^{3+} as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

Fe^{3+} is a monatomic cation (a single atom with a positive charge).

**47. True or False? If false, how could you rewrite the statement so that it is true?
Both covalent compounds and ionic compounds are composed of molecules.**

False.

Only covalent compounds are composed of molecules.

Ionic compounds are not composed of molecules,
but rather of cations and anions arranged in a continuous, solid array,
held together by the attractions between the cations and the anions.

The Review Quiz continues on the next page.

Let's continue our Review Quiz.

48. What types of compounds have we discussed in these lessons?

Covalent compounds and ionic compounds.

49. Is PCl_3 an ionic compound or a covalent compound?

Phosphorus (P) is a nonmetal.

Chlorine (Cl) is a nonmetal.

Since the formula contains only nonmetals,
we conclude that PCl_3 represents a *covalent* compound.

50. What is the net charge for Na_3PO_4 ?

There is no superscript shown, so the net charge for Na_3PO_4 is zero.

(Therefore, Na_3PO_4 is *not* a polyatomic ion, but an ionic compound.)

**51. Write the symbol for the ion likely to be formed by sulfur.
Is it a cation or an anion?**

Answer:
 S^{2-} anion

Analysis:
The closest noble gas to sulfur (S) in the periodic table is argon (Ar).

Argon is two steps to the right of sulfur in the table.
Therefore, in order to obtain an electron configuration similar to argon,
sulfur wants to gain two electrons,
resulting in an S^{2-} anion.

52. What is a “compound” defined as?

A compound is defined as a combination of two or more different elements
in a *fixed ratio*.

**53. What is the structure of an ionic compound?
What is the structure of a covalent compound?**

An ionic compound is a continuous, solid, three-dimensional array of cations and anions;
the array is held together by the attractions between the cations and anions;
the elements in the array appear in the ratio indicated by the compound's chemical formula.

A covalent compound is a collection of separate molecules;
the number of atoms of each element is indicated by the molecule's chemical formula;
the molecule is held together by covalent bonds between the atoms.

54. What is the net charge for NH_4^+ ?

The superscript is $^+$, which represents a +1 electric charge.

So the net charge for NH_4^+ is +1
(making it a polyatomic cation).

55. What holds a single ion of NH_4^+ together?

A single ion of NH_4^+ is held together by covalent bonds between the atoms.

**56. Write the symbol for the ion likely to be formed by magnesium.
Is it a cation or an anion?**

Answer:
 Mg^{2+} cation

Analysis:
The closest noble gas to magnesium (Mg) in the periodic table is neon (Ne).

Neon is two steps to the left of magnesium in the table.
Therefore, in order to obtain an electron configuration similar to neon,
magnesium wants to lose two electrons,
resulting in an Mg^{2+} cation.

**57. What are ionic compounds “based” on?
What are covalent compounds “based” on?**

An ionic compound is based on *transferring* electrons from one atom to another.

A covalent compound is based on *sharing* electrons between atoms.

58. What is the structure of the compound quicklime, CaO?
Give as much detail about as many layers of structure as possible.

CaO contains a metal and a nonmetal, so CaO is an ionic compound.

Quicklime is a continuous, solid, three-dimensional array of Ca^{2+} cations and O^{2-} anions; the array is held together by the attractions between the cations and anions; as indicated by the compound's chemical formula, Ca^{2+} cations and O^{2-} anions appear in a 1:1 ratio in the array.

59. Is AlF_3 an ionic compound or a covalent compound?

AlF_3 contains a metal and a nonmetal,
so we conclude that AlF_3 represents an *ionic* compound.

60. Classify S^{2-} as a monatomic cation, a monatomic anion, a polyatomic cation, a polyatomic anion, an ionic compound, a covalent compound, or a neutral molecule.

S^{2-} is a monatomic anion.

61. What is the term for a positively charged ion?
What is the term for a negatively charged ion?

A positively charged ion is called a *cation*.
A negatively charged ion is called an *anion*.

**62. Write the symbol for the ion likely to be formed by aluminum.
Is it a cation or an anion?**

Answer:
 Al^{3+} cation

Analysis:
The closest noble gas to aluminum (Al) in the periodic table is neon (Ne).

Neon is three steps to the left of aluminum in the table.
Therefore, in order to obtain an electron configuration similar to neon,
aluminum wants to lose three electrons,
resulting in an Al^{3+} cation.

**63. Write the symbol for the ion likely to be formed by potassium.
Is it a cation or an anion?**

Answer:
 K^{+} cation

Analysis:
The closest noble gas to potassium (K) in the periodic table is argon (Ar).

Argon is one step to the left of potassium in the table.
Therefore, in order to obtain an electron configuration similar to argon,
potassium wants to lose one electron,
resulting in a K^{+} cation.

You have reached the end of the lesson.

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

[Naming Ionic Compounds](#)