# Writing Formulae Notes

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A chemical formula is a universal shorthand that tells us exactly which atoms, and how many of each, are in a substance. The key is knowing that the rules depend on the type of bonding!

**Note**: Formulae is the plural of formula but we can also use the word formulas instead.

I'm sure that you have seen lots of formulae in chemistry. When you have looked at them you might have thought, "**oh, why does the formula look like that?**" The following are examples of formulae:

| $Al_2O_3$ | or | $C_2H_6$ |
|---|---|---|
| Aluminium oxide | | Ethane |

## Formulas – what do I need to know?

**What are they?** Formulas are a shorter way of writing the name of a molecule. Formulas give us a lot of information about the molecule.

**What do these formulas tell us?** They tell us about the numbers of each type of atom in the molecule.

Let's have a look at two different examples 😊

| | |
|---|---|
| $Al_2O_3$<br>Two aluminium atoms<br>Three oxygen atoms | $C_2H_6$<br>Two carbon atoms<br>Six hydrogen atoms |

**What are the small numbers?** These are called subsripts. In a formula these cannot be changed or you will change the identity of the molecule. For example, $Al_3O_4^+$ is not the same thing as $Al_2O_3$.

Writing formulas is a key skill in chemistry. Ionic and covalent formulas are written differently. Let's look at Ionic formulas first.

## Ionic Formulas – how do we write them?

Ionic compounds are made up of ions. Let's take a moment to remind ourselves what ions are.

**Ions**: are electrically charged particles that are formed when electrons are lost or gained from an atom.

**Cations**: are positive ions. **Anions**: are negative ions.

**Ionic formula rule**: the final formula must be electrically neutral, meaning the positive and negative charges must cancel each other out.

Take the following examples:

**Sodium Chloride**

$Na^+$ $Cl^-$

The charges are 1 plus to 1 minus.

So, the formula is just

$NaCl$

**Sodium Oxide**

$Na^+$ $O^{2-}$

The charges are 1 plus to 2 minuses.

So, we need two sodium ions to cancel out the oxide ion.

The formula then is:

$Na_2O$

**How do we figure out the charges of each of the ions?** We use the periodic table 😊

Check out the table below.

| Group in Periodic Table | What it does | Charge on its ion | Example |
|---|---|---|---|
| Group 1 (e.g. Na, K) | Loses 1 electron | +1 | $Na^+$ and $K^+$ |
| Group 2 (e.g. Mg, Ca) | Loses 2 electrons | +2 | $Mg^{2+}$ and $Ca^{2+}$ |
| Group 3 (e.g. Al) | Loses 3 electrons | +3 | $Al^{3+}$ and $Ga^{3+}$ |
| Group 5 (e.g. N, P) | Gains 3 electrons | –3 | $N^{3-}$ and $P^{3-}$ |
| Group 6 (e.g. O, S) | Gains 2 electrons | –2 | $O^{2-}$ and $S^{2-}$ |
| Group 7 (e.g. Cl, Br) | Gains 1 electron | –1 | $F^-$ and $Cl^-$ |

Now that we know how the charges are applied, let's look at another example 😊

**Example 1**: What is the formula for magnesium chloride? Let's do this step by step.

**Step 1: symbols and charges**: we write down the symbols for the ions.

Magnesium is in group 2 so it will <u>lose two electrons</u> to be a single $Mg^{2+}$ ion.

Chloride is in group 7 so it will <u>gain one electron</u> to become a $Cl^-$ ion.

**Step 2: swap and drop**: we <u>swap the charge numbers (without the charges) and drop them down</u> to become the subscript for the other ion. So right now we have the following ions…

$$Mg^{2+} \qquad Cl^-$$

**Swap** – we swap the charge numbers between the atoms but leave out the charges. This gives us…

$$Mg^1 \qquad Cl^2$$

**Drop** – we just drop down the numbers and use them as subscripts. This gives us…

$$Mg_1 \qquad Cl_2$$

**Step 3: we write the formula**: we now just put them together and leave out the number one.

$$MgCl_2$$

Let's, look at another example of an ionic compound.

**Example 2:** What is the formula for aluminium hydroxide?

**Step 1: symbols and charges**: we write down the symbols for the ions.

Aluminium is in group 3 so it will <u>lose three electrons</u> to be a single $Al^{3+}$ ion.

Hydroxide is a group ion whose formula we must learn. This is an $OH^-$ ion.

**Step 2: swap and drop**: we <u>swap the charge numbers (without the charges) and drop them down</u> to become the subscript for the other ion.

$$Al^{3+} \qquad OH^-$$

$$Al_1 \qquad OH_3$$

**Step 3: we write the formula**: we now just put them together and leave out the number one.

$$Al(OH)_3$$

That's it 😊

## Transition Metal Formulas – how do we write them?

Transition metal formulae are a slightly different version of ionic formulae. Transition metals can have different charges. Iron, for example, can be $Fe^{2+}$ or $Fe^{3+}$, how can I tell which one to use?

The formula will tell you the charge using roman numerals. So, $Fe^{2+}$ will be Fe(II) and $Fe^{3+}$ will be Fe(III).

**Metal ions**: metals always form cations (positive ions).

**Formula rule**: just like ionic formulae, the charges of each ion in the molecule must cancel each other out.

Let's have a look at a couple of examples.

**Example 3:** What is the formula for iron(II) oxide?

**Step 1: symbols and charges**: we write down the symbols for the ions.

Iron is a transition metal so we need to use the roman numerals that go with it to determine its charge, in this case it will be $Fe^{2+}$.

Oxygen is in group 6 so it will gain two electrons to become a $O^{2-}$ ion.

**Step 2: swap and drop**: we swap the charge numbers (without the charges) and drop them down to become the subscript for the other ion. So right now we have the following ions…

$$Fe^{2+} \qquad O^{2-}$$

$$Fe_2 \qquad O_2$$

**Note**: as the subscript numbers are the same we can just simplify by dividing by 2.

**Step 3: we write the formula**: we now just put them together.

$$FeO$$

**Example 4**: What is the formula for copper(II) nitrate?

**Step 1: symbols and charges**: we write down the symbols for the ions.

Copper is a transition metal so we need to use the roman numerals that go with it to determine its charge, in this case it will be $Cu^{2+}$.

Nitrate is a group ion who's formula we must learn is an $NO_3^-$ ion.

**Step 2: swap and drop**: we swap the charge numbers (without the charges) and drop them down to become the subscript for the other ion. So right now we have the following ions…

$$Cu^{2+} \qquad NO_3^-$$

$$Cu \qquad (NO_3)_2$$

**Step 3: we write the formula**: we now just put them together.

$$Cu(NO_3)_2$$

## Covalent Formulas – how do we write them?

Covalent compounds are made up of atoms that **share electrons** so that they can have full outer shells of electrons.

**Covalent formula rule**: each atom should have a full other shell of electrons.

A few handy bonding points to remember are that carbon always forms **four bonds**, oxygen always forms **two bonds** and hydrogen always forms **one bond**.

**How do we know how many bonds an atom will form?**
For non-metals, there is a simple pattern linked to the periodic table. This number is sometimes called its **valency**.

| Group in Periodic Table | What it does to get a full outer shell | Bonds it forms (Valency) |
|---|---|---|
| Group 4 (e.g. C, Si) | Needs to gain 4 electrons | 4 |
| Group 5 (e.g. N, P) | Needs to gain 3 electrons | 3 |
| Group 6 (e.g. O, S) | Needs to gain 2 electrons | 2 |
| Group 7 (e.g. Cl, Br) | Needs to gain 1 electron | 1 |
| Hydrogen (special case) | Needs to gain 1 electron | 1 |

**Note**: a handy little shortcut is to take the group number away from 8. This will work for groups 4 to 7.

**Bonds formed = 8 – group number**

Let's have a look at an example 😊

**Example 5**: What is the formula for water?

**Step 1 – symbols and valency**: we state the symbols and the number of bonds each atom needs to form.

Hydrogen (H) needs to form 1 bond.

Oxygen (O) is in group 6 and needs to form 2 bonds.

**Step 2 – swap and drop**: we can use the same "swap and drop" method as for ionic formulae, but remember these numbers represent the number of bonds that each atom needs to form, not the ionic charges!

We swap the valency numbers and they become the subscript for the other atom.

H – valency 1 O – valency 2

$H_2$ $O_1$

**Step 3 – write the formula**: We now just put them together and leave out the number one.

$H_2O$

This makes sense! One oxygen atom needs to make 2 bonds. Each hydrogen atom can only make 1 bond.
So, the oxygen atom must bond with two hydrogen atoms. 😊

## Common Ions

Here are a few common ions that we must learn off by heart… You're welcome 😊

Ammonium – $NH_4^+$

Hydroxide – $OH^-$

Nitrate – $NO_3^-$

Hydrogencarbonate – $HCO_3^-$

Sulfate – $SO_4^{2-}$

Carbonate – $CO_3^{2-}$