A Chemistry Guide

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Everything presented here is to help you understand, learn, and how to a tackle problem. It is not intended to do you work. That is for you to do to be successful in life as you always have to learn personally, academically, and in work-related areas. Without further ado, let's learn science! 🤓

Balancing Chemical Equations

To balance chemical equations, you need to have an equal number of the chemical substances on both sides of the equation. Here is a generic chemical equation where an arrow is in the middle:

$$\mathrm{A} + \mathrm{B} \longrightarrow \mathrm{C}$$

The variables such as A or B could be any type of chemical substance such as water $\mathrm{H_2O}$, carbon dioxide $\mathrm{CO_2}$, an organic compound such as vinegar $\mathrm{CH_3COOH}$, or it could also have isotopes such as deuterium $^{2}\mathrm{H}$. The possibilities are almost endless. Physical states are sometimes shown as a lowercase letter with parenthesis around it such as liquid (l), solid (s), gas (g), or aqueous (aq). Lastly, energy could appear in the chemical equation from either the left side of right side as so: $\mathrm{CH_4\,(g)} + 2\,\mathrm{O_2\,(g)} \longrightarrow \mathrm{CO_2\,(g)} + 2\,\mathrm{H_2O\,(l)} + 890\ \mathrm{kJ}$.

There are two more important things to talk about which are **what type of arrows there are** and **what type of reactions there are**. Firstly, know that the left side of the arrow are called reactants while the right side of the arrow are called products. For **type of reactions**, there is a ***single replacement*** reaction where one chemical substance (C) that was together (AC) switches to another chemical substance that was alone (B) to form a new chemical compound (BC) while leaving the other by itself (A) such as this: $\mathrm{AC} + \mathrm{B} \longrightarrow \mathrm{A} + \mathrm{BC}$. There is also a ***double replacement*** reaction where one substance (C) that was once together as a compound (AC) swaps with another substance (D) that was also once together with its former compound (BD) to form two new compounds $(\mathrm{AD}$ and $\mathrm{BC})$ as shown: $\mathrm{AC} + \mathrm{BD} \longrightarrow \mathrm{AD} + \mathrm{BC}$. There is also a ***synthesis*** reaction that has two substances at the reactant side forming into one substance at the product side: $\mathrm{A} + \mathrm{B} \longrightarrow \mathrm{C}$. Lastly, there is ***decomposition*** where there is one substance at the reactant side that splits off into two different substances at the product side: $\mathrm{C} \longrightarrow \mathrm{A} + \mathrm{B}$.

For **type of arrows**, you could have the usual one $\longrightarrow$ which means the the reaction is going in the forward direction, or a net forward reaction from reactants to products. There is also one where you have both arrows pointing in opposite directions $\rightleftarrows$ or this $\leftrightharpoons$. I won't go into details about these since they are advanced topics, but this one $\rightleftharpoons$ is used for equilibrium where the forward rate is equivalent to the reverse rate. At the university and career level in the workforce, self-studying this is important if you want to know more about equilibriums.

Finally, to the problem!

Let's say there is a problem and we needed to balance it:

$$\mathrm{KBr} + \mathrm{Fe(OH)_3} \longrightarrow \mathrm{KOH} + \mathrm{FeBr_3} \tag{1}$$

On the reactants (left side) are potassium K, bromide Br, and iron Fe which are the same as the products (right side), but what about hydroxide OH? The formula for it are the same as both sides since O is before H and they never leave each other? So, should it be considered as just O separate from H? In this case, it is easier to have both as one compound as OH instead of two different substances separated from each other. BUT, you could have them separated if you want.

Now, we need to count how many numbers does K, Br, Fe, and OH have, and to know that is by looking at the subscripts which are at the bottom-right of the compound/substance as so: Br_3. If the compounds/substances do not have subscript numbers, then it is considered to be an invisible 1. As you can see from (1) on the reactant side, OH has 3. What this means is there are literally three of them. Still on the reactant side, K, Br, and Fe has only 1 since there are no subscript numbers shown, but it is *invisible*; and this also literally means that each of them only has one. Here is a better visualization of the reactants (left side) of (1) with their charges:

$$K^{1+}Br^{1-} \quad \begin{array}{l} OH^{1-} \\ Fe^{3+}OH^{1-} \\ OH^{1-} \end{array}$$

On the products side from (1), there is one K, OH, and Fe, but there is only three Br. Here is a visualization for it:

$$K^{1+}OH^{1-} \quad \begin{array}{l} Br^{1-} \\ Fe^{3+}Br^{1-} \\ Br^{1-} \end{array}$$

The complete visualization of (1) looks like this:

$$K^{1+}Br^{1-} \quad + \quad \begin{array}{l} OH^{1-} \\ Fe^{3+}OH^{1-} \\ OH^{1-} \end{array} \quad \longrightarrow \quad K^{1+}OH^{1-} \quad + \quad \begin{array}{l} Br^{1-} \\ Fe^{3+}Br^{1-} \\ Br^{1-} \end{array}$$

As you can see, there are unequal amount of chemical substances on both the left and right side: Br has 1 at the left, but it has 3 on the right; OH has 3 on the left, but it has 1 on the right; and both K and Fe have an equal amount of 1 on both sides. This needs to be balanced. I'll use a table to tally how much chemical substances we need along with a visualization, but in your case it is probably best to stick with a table due to time constraints on tests and other class works/activities. But, if you need to use a visualization then do it.

Substance	**Reactant**	**Product**
K	1	1
Br	1	3
Fe	1	1
OH	3	1

Based on this table, both K and Fe are balanced: They have the same number on both sides. What is not balance are Br with 1 on the left and 3 on the right, and OH with 3 on the left and 1 on the right. Let's attack Br: We cannot decrease the **Product** from 3 to 1 because there is no way to decrease it. We could only *increase* that chemical substance. This is due to Entropy where basically things become more disorder, or chaotic, as time increases. Since we can't ***decrease*** the **Product**, what we can do is ***increase*** the **Reactant** for Br, but how do we do that? Simple, we multiply it, but why? That is because as you increase the chemical substance, you are also increasing its factor, and the factor is whatever number you are given. In this case, Br has a factor of 1 in the **Reactant** side, and to increase from 1 to 3 is to increase its factor by 3: $1 \times 3 = 3$:

Substance	Reactant	Product
K	1	1
Br	$1 \times 3 = \mathbf{3}$	3
Fe	1	1
OH	3	1

If this is a little difficult to understand, then remember that multiplication is basically a shortcut to addition: Instead of adding all the numbers, we could multiply the factor which is the given value. For example, in 1 hour is 60 minutes. How many minutes are in 5 hours? We need to change the given value, or ***factor***, of 60 minutes by 5: $60 \times 5 = 300$. So, there are 300 minutes in 5 hours. We could have added: For $1+1+1+1+1=5$ hours there are $60+60+60+60+60=300$ minutes. Which is easier to do: Multiplication or Addition? For numbers that are large, multiplication is easier and faster than adding them all together. For smaller numbers, addition could be easier. In this case, we used multiplication as a shortcut to balance Br: For 3 **Product**, we need $1 \times 3 = 3$ **Reactant** INSTEAD OF doing $1+1+1=3$ **Reactant**.

Now, since we put a 3 in the table, this means that there are three Br on reactant side (left side). Let's look at it visually:

$$\begin{array}{ccccccc} & \mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & & & \mathrm{Br}^{1-} \\ \mathrm{K}^{1+} & \mathrm{Br}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{OH}^{1-} & \longrightarrow & \mathrm{K}^{1+}\mathrm{OH}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{Br}^{1-} \\ & \mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & & & \mathrm{Br}^{1-} \end{array}$$

Notice how there are three Br on the left side? Also notice how the negative charges of Br add up to $3-$. BUT, also notice how the positive charges of K on the left side add up only to $1+$? The charges also need to be balanced, and we could do this by adding two more K:

$$\begin{array}{cccccc} \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & & & \mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{OH}^{1-} & \longrightarrow & \mathrm{K}^{1+}\mathrm{OH}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & & & \mathrm{Br}^{1-} \end{array}$$

BUT, since there is three K, that means that the factor of 1 got multiplied by 3 on the table (I know this is getting weird, but bear with me. I'm getting there):

Substance	Reactant	Product
K	$1 \times 3 = \mathbf{3}$	1
Br	$1 \times 3 = 3$	3
Fe	1	1
OH	3	1

What does this all mean. Remember when I said earlier that multiplication is a shortcut to addition? The table is the shortcut to the visual: When you do the table, you are using the multiplication method. When you are using the visual, you are using the addition method. I'll repeat it: You use the visual for addition while you use the table for multiplication.

Reviewing on what we just did: There was one factor of Br on the **Reactant** side so we had to multiply that factor by 3, but this in turn affected K since it was uneven to Br so we had to increase the factor of K as well. For now, I will be calling the table as the Table Method and the visual as the Visual Method. Let's continue.

Based on the table above, the chemical substances Br and Fe are balanced with equal numbers on the left and right side, but K and OH are not balanced. Let's attack K by increasing its **Product** factor of 1 to 3: $1 \times 3 = 3$. Lets show this on the Table Method:

Substance	**Reactant**	**Product**
K	$1 \times 3 = 3$	$1 \times 3 = \mathbf{3}$
Br	$1 \times 3 = 3$	3
Fe	1	1
OH	3	1

Let's see this on the Visual Method where there are now three K on the right side:

$$\begin{array}{lllllll} \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & \mathrm{K}^{1+} & & \mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{OH}^{1-} & \longrightarrow & \mathrm{K}^{1+}\mathrm{OH}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & \mathrm{K}^{1+} & & \mathrm{Br}^{1-} \end{array}$$

The K charges add up to $3+$ on the right side, but the OH charges only add up to $1-$. It's unbalanced and we need to increase its **Product** factor of 1 to 3. Let's use the Table Method where $1 \times 3 = 3$:

Substance	**Reactant**	**Product**
K	$1 \times 3 = 3$	$1 \times 3 = 3$
Br	$1 \times 3 = 3$	3
Fe	1	1
OH	3	$1 \times 3 = \mathbf{3}$

There should now be three OH on the right side for the Visual Method:

$$\begin{array}{lllllll} \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & \mathrm{K}^{1+}\mathrm{OH}^{1-} & & \mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{OH}^{1-} & \longrightarrow & \mathrm{K}^{1+}\mathrm{OH}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & \mathrm{K}^{1+}\mathrm{OH}^{1-} & & \mathrm{Br}^{1-} \end{array}$$

By looking at the Visual Method above, you might be thinking that Fe is unbalanced since there is only one compared to three, but that is not true. For the Visual Method, you decide if it is balanced by counting the charges, and if the substances have the same amount on both sides (three K on both left and right side). For the Table Method, you decide if it is balanced by checking if there are equal numbers on the **Reactant** side and **Product** side. You use the Visual Method for addition while you use the Table Method for multiplication.

Let's check if it is balance:

- For the Table Method, there are equal numbers of 3 for K, Br, and OH while there is an equal number of 1 for Fe on the **Product** and **Reactant**.
- For the Visual Method, there are 3 equal substances of K, Br, and OH and 1 equal substance of Fe on the left side and right side. There are $3+$ charges for K balancing with

3$-$ charges for Br on the left side, $3+$ charge for Fe balancing with $3-$ charges for OH on the left side, $3+$ charges for K balancing with $3-$ charges for OH on the right side, and $3+$ charge for Fe balancing with $3-$ charges for Br on the right side.

Everything is balanced, but we are nearly done. All we have to do is put the numbers that we just got into (1) for the final answer. To do this, look at either the Table Method or Visual Method or both. I'll do both. Here is (1) as a reference along with the Table Method and Visual Method:

Substance	**Reactant**	**Product**
K	$1 \times 3 = 3$	$1 \times 3 = 3$
Br	$1 \times 3 = 3$	3
Fe	1	1
OH	3	$1 \times 3 = 3$

$$\begin{array}{ccccccc} \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & \mathrm{K}^{1+}\mathrm{OH}^{1-} & & \mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{OH}^{1-} & \longrightarrow & \mathrm{K}^{1+}\mathrm{OH}^{1-} & + & \mathrm{Fe}^{3+}\mathrm{Br}^{1-} \\ \mathrm{K}^{1+}\mathrm{Br}^{1-} & & \mathrm{OH}^{1-} & & \mathrm{K}^{1+}\mathrm{OH}^{1-} & & \mathrm{Br}^{1-} \end{array}$$

$$\mathrm{KBr} + \mathrm{Fe(OH)_3} \longrightarrow \mathrm{KOH} + \mathrm{FeBr_3}$$

On the **Reactant** side or left side: The Table Method shows that there are $3\,\mathrm{K}$ and $3\,\mathrm{Br}$ which the Visual Method also shows on the left side. So, the factor of KBr goes to 3. **IMPORTANT** 🚨: You do not add the two numbers together! Think about it. Let K be an apple while Br be an orange. Can you add these two to get 6? No, but an apple and an orange together form a basket of fruits. The same with K and Br where together they form a compound, and we have three compounds of KBr. So, a 3 goes in front of KBr as so:

$$3\,\mathrm{KBr} + \mathrm{Fe(OH)_3} \longrightarrow \mathrm{KOH} + \mathrm{FeBr_3}$$

Still on the **Reactant** side: The Table Method shows that both Fe and OH were not changed with $1\,\mathrm{Fe}$ and $3\,\mathrm{OH}$ which the Visual Method also shows on the left side with equal charges of $3+$ and $3-$. This means that they form 1 compound of $\mathrm{Fe(OH)_3}$ since for every $1\,\mathrm{Fe}$ you need at least $3\,\mathrm{OH}$:

$$3\,\mathrm{KBr} + 1\,\mathrm{Fe(OH)_3} \longrightarrow \mathrm{KOH} + \mathrm{FeBr_3}$$

On the **Product** side: The Table Method shows that there are $3\,\mathrm{K}$ and $3\,\mathrm{OH}$ which the Visual Method also shows on the right side. They form into KOH compound, and we have three of them:

$$3\,\mathrm{KBr} + 1\,\mathrm{Fe(OH)_3} \longrightarrow 3\,\mathrm{KOH} + \mathrm{FeBr_3}$$

Last of all on the **Product** side: The Table Method shows that both Fe and Br remain unchanged with $1\,\mathrm{Fe}$ and $3\,\mathrm{Br}$ which the Visual Method also shows on the right side: equal charges of $3+$ and $3-$. This means that they form 1 compound of $\mathrm{FeBr_3}$ since for every $1\,\mathrm{Fe}$ you need at least $3\,\mathrm{Br}$. And so the final answer is:

$$\boxed{3\,\mathrm{KBr} + 1\,\mathrm{Fe(OH)_3} \longrightarrow 3\,\mathrm{KOH} + 1\,\mathrm{FeBr_3}}$$

That is how you Balance Chemical Equations! Congrats for making it this far! 👨‍🎓 👏 🎊 🏆

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Hopefully everything made sense in this document, but if you have any questions then please contact your Case Manager(s) or Teacher(s) for further information. Thank you and have a very good day!