

# Campus Academic Resource Program

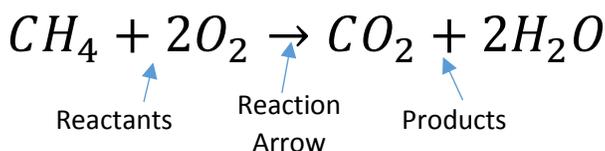
## Balancing Equations

### Balancing Equations

This handout will:

- Introduce the parts of a reaction equation and key terms
- Explain how to organize a table with the amounts of all of the elements involved
- Discuss how to identify the order of which elements to balance
- Cover how to deal with fractional coefficients

### The Parts of a Chemical Reaction



### Key Terms

$\text{CH}_4$  is a **species** within the chemical reaction (same with  $\text{O}_2$ ,  $\text{CO}_2$ , and  $\text{H}_2\text{O}$ ), these have more than one element composing a molecule.

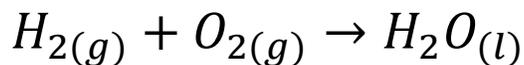
Within the **species**  $\text{CH}_4$ ; carbon, and hydrogen are the **elements** and the 4 in the species indicates there are 4 hydrogen atoms within the species  $\text{CH}_4$ .

**Coefficients** are numbers we place in front of the **species** to indicate how many mols are needed for a balanced equation to occur, this number is important for counting the total number of each element.

**Example:** If we have a molecule of  $\text{H}_2$  we have 2 hydrogens. If we have  $2\text{H}_2$  we have  $(2*2) = 4$  hydrogens.

### How to balance a Chemical Reaction

Since chemical equations deal with taking the reactant species and recombining the elements to create the product species, **we must make sure we keep the amounts of each element the same on both sides of the chemical equation<sup>1</sup>**. We can't have a mole of anything disappearing from one side to the other (as we see with Oxygen in the unbalanced reaction below), it needs to still be in one of the product species.



- **The first step** to balancing an equation is to count up the number of elements on each side of the given reaction.

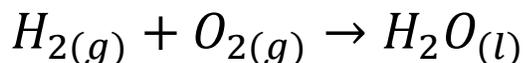
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<sup>1</sup> For more information on why we balance chemical equations, visit:  
[http://www.wyzant.com/resources/lessons/science/chemistry/chemical\\_equations](http://www.wyzant.com/resources/lessons/science/chemistry/chemical_equations)

# Campus Academic Resource Program

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One way that we will use to keep track of the elements on each side of the reaction is to build a table that we can fill in. When we have species involved in the equation, we should count them as their individual elements to help us keep track of them on both sides.

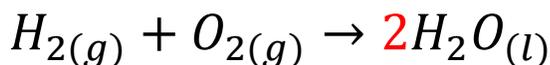


Reactants	Products
H 2	H 2
O 2	O 1

As we can see from this table, we don't have an equal amount of both elements on both sides of the equation. How do we fix this?

- **The second step** to balancing an equation is to identify the species that contains the smaller amount of the unbalanced element and determine what coefficient to add in front of the species that makes the numbers of the unbalanced element the same.

We see from the table above that the products side was lacking an oxygen in the water molecule. So we need to add another mol of  $H_2O$  so that there are 2 oxygens in the reactants, so now there will be 2 oxygens in the products.

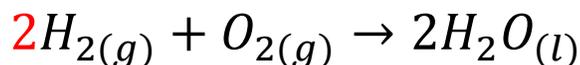


Reactants	Products
H 2	H 4
O 2	O 2

Keep in mind that by increasing the number of oxygen to 2, we have to re-count the hydrogens in the water molecule, giving us  $2H_2 = 2 \cdot 2 = 4$  hydrogens. This gives us another unbalanced amount of elements between the two sides.

- **The third step** to balancing is to identify the next species that contains the smaller amount of unbalanced element and add a coefficient to the species to make the numbers of the unbalanced element the same.

We now have 4 hydrogens in the products side in the  $2H_2O$  molecules, but only 2 hydrogens in the  $H_2$  species of the reactants. We can fix this by adding another mol of  $H_2$  because that adds 2 more hydrogens.



## Campus Academic Resource Program

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Reactants	Products
H 4	H 4
O 2	O 2

Now that we have added another mol of  $H_2$  we can see by our table that the elements are all balanced, making this our answer. We are done!

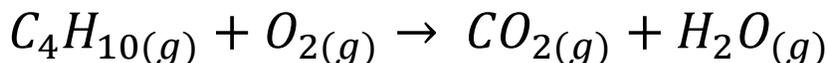
#### Making Decisions on Which element to balance

Balancing the above equation only involved two elements and one product species. There are equations that you will run across that involve 3 or more elements and multiple product species, and there is a strategy to figuring out what to balance first.



This is a combustion reaction. It will introduce us to the challenges of having more than 2 elements involved and of having fractional coefficients. We can solve this problem with the same methods we used in the last example, there are just a few more questions to ask yourself.

- **The First Step** is to make a table, like the first example, and to count the elements on either side of the equation.



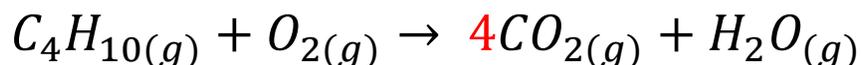
Reactants	Products
C 4	C 1
H 10	H 2
O 2	O 3

We can notice that all three of our elements are unbalanced. The real question to ask now is: Which element should we try to balance first?

The answer to this question is not exact; you could start with ANY of the three elements. But, there are some guidelines that will help you get the answer with less hassle.

- You should leave hydrogen and oxygen for last
- You should identify which element occurs in only one species on either side of the equation as the first element to balance.
- You should double the entire equation if you are left with a fraction coefficient (common with oxygen)

The element we should focus on, based on the above guidelines, is carbon. It shows up in only one species on both sides, and we know to leave hydrogen and oxygen alone.



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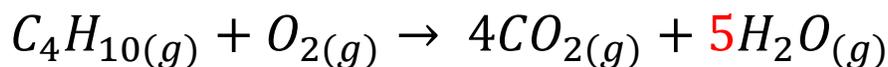
Reactants	Products
C 4	C 4
H 10	H 2
O 2	O 9

We can see from the table that, by balancing our carbons, we have changed the amount of oxygen in the products (carbon dioxide) and we can see that the other product species (water) has oxygen in it as well. This can help us determine which element to balance next

- **The Second Step** would be to figure out which of the two elements to balance next: hydrogen or oxygen.

When we are considering the two left over and unbalanced elements, we should look back to the guidelines above and ask ourselves, “Which element only occurs in one species on either side of the equation?”

The answer, as we can see below, is hydrogen! So we should try to balance it.



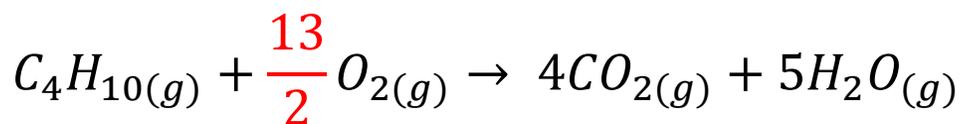
Reactants	Products
C 4	C 4
H 10	H 10
O 2	O 13

Now that we have the hydrogens matching on both sides we can see that our oxygen is the last element unbalanced, and we can see that there are an odd number of them. This is a problem. We can see that oxygen comes in pairs, as  $O_2$ , so how do we get an odd amount in the reactants?

There are two ways:

- **The Third Step (A)** would be to use a fraction to balance the  $O_2$  species.

We need to get 13 atoms of oxygen, and we have 2 to begin with. The way to balance this is to use a fractional coefficient to get half of the  $O_2$  molecule. If we need to have 13, and we have to consider that the coefficient is multiplied by 2, we can put our target amount of 13 over 2 to cancel that multiplication:  $\frac{13}{2} \cdot 2 = 13$



Reactants	Products
C 4	C 4
H 10	H 10

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O 13	O 13
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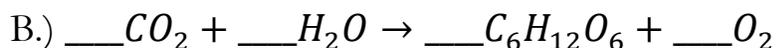
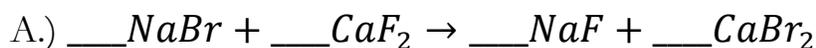
- **The Third Step (B)** would be to double the entire reaction by multiplying each coefficient by 2, which will give us an even amount of oxygen in the products. Therefore, we are able to simply put a coefficient in front of the  $O_2$  species.



Reactants	Products
C 8	C 8
H 20	H 20
O 26	O 26

Now you can see that the equation is balanced! With more complex equations you may be required to repeat any of these three steps until you get the final, balanced product.

#### Practice:



A.) 2, 1, 2, 1      B.) 6, 6, 1, 6

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### References

Silberberg, M. (2009). Stoichiometry of Formulas and Equations. In Chemistry: The molecular nature of matter and change (5th ed., pp. 104-109). New York, New York: McGraw-Hill.