

Chapter 7

Balancing Molecular Equations

Chemists write chemical equations to illustrate what is happening during a chemical reaction—bonds are broken, atoms are rearranged and new bonds are formed. Every chemical reaction supports the Law of Conservation of Matter. This means that in every reaction, the number of atoms of each type of element contained within the reactants must be the same as the number of atoms of each type of element contained within the products.

Balancing equations is a process which assures that equations are written properly to support the Law of Conservation of Matter; however, balancing cannot be done until each reactant and product formula is written correctly. It is important to properly write the seven elements that are diatomic in their elemental form and also to use subscripts and parentheses appropriately when considering the oxidation numbers of ions. All compounds must be made neutral before beginning to balance atoms.

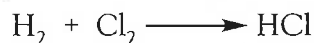
Balancing is accomplished by adding coefficients that multiply the number of atoms represented by the formula. For example, a coefficient of 2 in front of oxygen (e.g., 2O_2) means that 4 oxygen atoms are represented. Unlike algebra, in chemistry a coefficient does not need to be outside parentheses or brackets to be distributed. A coefficient applies to the complete substance; however, it no longer applies when a plus sign (+) or arrow (\longrightarrow) is encountered. For example,

$3(\text{NH}_4)_2\text{CO}_3$ shows 6 nitrogen, 24 hydrogen, 3 carbon and 9 oxygen atoms

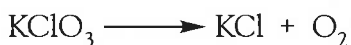
$3\text{MgCl}_2 + \text{NaBr}$ indicates 3 magnesium, 6 chlorine, 1 sodium and 1 bromine atom

Tips for Balancing Equations

- Be sure each molecular formula is written correctly and each compound is neutral.
- Mentally count or tally how many of each type of atom is present on each side of the equation.
- Begin by balancing elements that are only found in one substance on each side.
- Balance oxygen and hydrogen *last*—they usually balance out at the end or perhaps only the number of water molecules will need to be adjusted.
- If there is an odd number of an element on one side and an even number on the other, the odd number will need to be evened out—so use a coefficient of 2 for that substance.
- If there are polyatomic ions that remain together as a unit during the reaction, count the polyatomic ion as a unit.
- When tallying, be sure to adjust the count for each and every element that an added coefficient affects.
- Combustion reactions that don't seem to balance will often come out better if a coefficient of 2 is used for the hydrocarbon.

Some Examples**Hydrogen and chlorine gases react to form hydrogen chloride gas.**

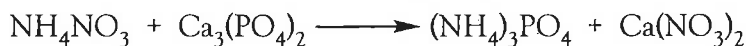
Because one hydrogen and one chlorine atom appears to have been lost, a coefficient of 2 is added to the HCl.

**Potassium chlorate is heated and decomposes into potassium chloride and oxygen gas.**

Because there is an odd number of oxygen atoms on the left and an even number on the right, a coefficient of 2 is added to the potassium chlorate.



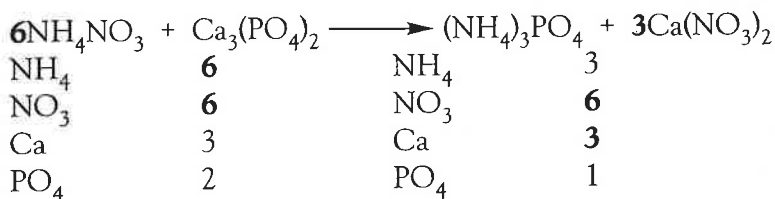
The oxygen atoms can now be balanced using a coefficient of 3; the potassium and chlorine atoms can be balanced using a coefficient of 2 in front of KCl.

**Ammonium nitrate reacts with calcium phosphate to form ammonium phosphate and calcium nitrate.**

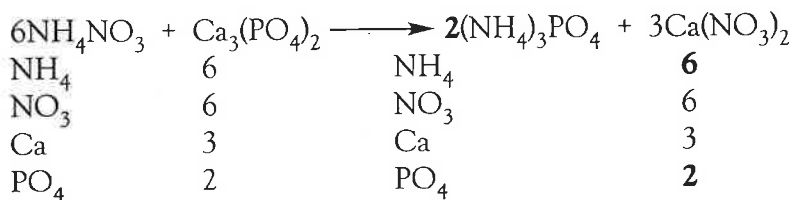
Balancing this equation can be simplified greatly by noticing that each of the polyatomic ions remain together as a group throughout the reaction. Note that the tallying below indicates this.



Beginning with calcium, add a coefficient of 3 on the right to balance the Ca. This also changes the nitrate count to 6 on the right, so adjust that by adding a coefficient of 6 on the left side.



Finally, a coefficient of 2 is needed in front of ammonium phosphate to complete the balancing.



As a double check, it is always wise to count the total number of each type of element indicated. For this reaction there is a total of 12 N, 24 H, 26 O, 3 Ca and 2 P atoms on each side.

Now it is time to apply the rules for balancing equations to some chemical reactions. It turns out that many chemical reactions can be organized into various groups—that is the focus of the sections that follow.

Exercise 7-1: Balance the following equations by adding coefficients as needed. Some equations may already be balanced.

1. $\text{Ca} + \text{HOH} \longrightarrow \text{Ca}(\text{OH})_2 + \text{H}_2$
2. $\text{Cl}_2\text{O}_7 + \text{H}_2\text{O} \longrightarrow \text{HClO}_4$
3. $\text{Fe} + \text{O}_2 \longrightarrow \text{Fe}_3\text{O}_4$
4. $\text{C}_6\text{H}_{14} + \text{O}_2 \longrightarrow \text{CO}_2 + \text{H}_2\text{O}$
5. $\text{Ca}_3(\text{PO}_4)_2 + \text{H}_2\text{SO}_4 \longrightarrow \text{Ca}(\text{H}_2\text{PO}_4)_2 + \text{CaSO}_4$
6. $\text{AlCl}_3 + \text{AgNO}_3 \longrightarrow \text{Al}(\text{NO}_3)_3 + \text{AgCl}$
7. $\text{HCl} + \text{CaCO}_3 \longrightarrow \text{CO}_2 + \text{HOH} + \text{CaCl}_2$
8. $\text{WO}_3 + \text{H}_2 \longrightarrow \text{W} + \text{H}_2\text{O}$
9. $\text{Cl}_2 + \text{H}_2\text{O} \longrightarrow \text{HCl} + \text{HClO}$
10. $\text{Cl}_2 + \text{NaI} \longrightarrow \text{NaCl} + \text{I}_2$