

Chemical Equations and Reaction Types

The purpose of this laboratory exercise is to develop skills in writing and balancing chemical equations. The relevance of this exercise is illustrated by a series of demonstration reactions, performed by your lab instructor, which will provide a model to enable the student to predict the products and write balanced chemical equations for a series of similar reactions.

In order to write a balanced chemical reaction, two skills must be mastered.

- 1) Describe the chemical process: write correct chemical formulas for reactants, predict products and write correct chemical formulas for the products of the chemical reaction.
- 2) Balance the chemical equation.

A chemical equation is a shorthand way of expressing a chemical change in terms of symbols and formulas. An equation for a reaction cannot be written unless the substances that are reacting and being formed are both known. For an equation to be considered correct, it must be balanced. That is, the number of atoms of each element on the left side of the equation must equal the number of atoms of the same element on the right side. This is an application of the Law of Conservation of Mass. Equations may be written in two general ways: as molecular equations and as ionic equations. We shall only consider molecular equations in this exercise.

There are several conventions which are used in writing chemical equations:

- 1) The reactants are placed on the left side of the equation and the products on the right side with a single arrow separating the reactants from the products.
- 2) A plus sign (+) separates each reactant or each product.
- 3) The physical state of the chemical is often listed as a subscript. (i.e. $\text{H}_2\text{O}_{(l)}$ and $\text{NaCl}_{(s)}$)
- 4) A symbol may be placed above the arrow to indicate conditions needed for the reaction to occur; for example: Δ indicates that heat must be applied.

Guidelines for balancing chemical equations

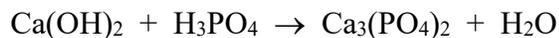
The chemical equations we will encounter in this exercise are balanced "by inspection". The following guidelines are just helpful suggestions to facilitate the balancing process.

- 1) Determine the type of reaction (i.e. combination, decomposition, replacement, etc.)
- 2) Write the correct formula for reactants. Once the correct formula is written it must not be changed during the subsequent balancing operation.

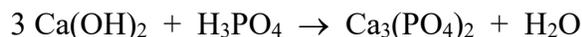
*Note: The seven diatomic elements, when uncombined, are written with subscripts of 2 (H_2 ; O_2 ; etc.)

- 3) Determine the products and write the correct formula for each product. Once the correct formula is written it must not be changed during the subsequent balancing operation.
- 4) Balance the chemical equation. Do NOT change any chemical formulas while balancing.
 - a) Choose the compound with the greatest number of atoms (excluding H and O) and balance the number of atoms of that element on both sides of the equation. This is done by placing the appropriate coefficient in front of the formula of the element or compound on the other side of the arrow that contains that same element. The coefficient is chosen so that when the coefficient is multiplied by the subscript for that element, the number of atoms of that element is equal to the number of atoms of the same element on the other side of the arrow.
 - b) Continue until the number of atoms of each element is the same on both sides of the arrow.
 - c) Check all coefficients to see that they are whole numbers and the lowest possible ratio.

The following example illustrates these guidelines.



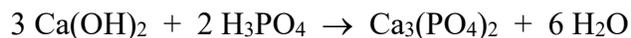
Start by balancing the calcium atoms in calcium phosphate first, since calcium phosphate contains the most atoms of an element other than H or O. This requires a coefficient of 3 to be placed in front of Ca(OH)_2 on the other side of the arrow.



Next balance the phosphate (if a polyatomic is found on both sides of the equation, it is easier to balance for the polyatomic than as each type of element) by putting a 2 in front of H_3PO_4 .



The hydrogen atoms now total 12 on the left side, 6 from the 3 Ca(OH)_2 "molecules" and 6 from 2 H_3PO_4 molecules. Therefore, place a 6 in front of the formula for water and the equation will be balanced.



All coefficients should be **whole numbers** and the **lowest possible ratio**.

Categories of Chemical Reactions:

Most chemical reactions can be grouped into one of four categories:

- 1) **Combination reactions** $A + B \rightarrow X$
- 2) **Decomposition reactions** $X \rightarrow A + B$
- 3) **Single replacement reactions** $A + BX \rightarrow AX + B$
(Metal replace metals; non-metals replace non-metals.)
- 4) **Double displacement reactions** $AX + BY \rightarrow AY + BX$
 - a) Precipitation (solid forms)
 - b) Acid/Base (water is formed) [sometimes called neutralization]

Knowledge of the kind of reaction is useful in predicting the products in a particular reaction. Your instructor will demonstrate several reactions of each category, predicting the products, writing and balancing the chemical equation in each case. Using these as models, you will write and balance chemical equations of similar reactions.

B. DECOMPOSITION: $X \rightarrow A + B$

- 1) The decomposition of ammonium dichromate, $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$, into nitrogen, water, and chromium(III) oxide.
- 2) The decomposition of nitrogen triiodide into its elements.
- 3) The decomposition of potassium chlorate to potassium chloride and oxygen.
- 4) The thermal decomposition of ammonium carbonate into ammonia, carbon dioxide and water
- 5) The decomposition of lead(IV) oxide into its elements.

C. SINGLE REPLACEMENT: $AX + B \rightarrow BX + A$

- 1) The reaction of a solution of silver(I) nitrate with copper metal (copper(II) nitrate is a product).
- 2) The reaction of sodium metal with water to create hydrogen gas and sodium hydroxide.
- 3) Zinc metal with sulfuric acid (zinc(II) sulfate is a product).
- 4) Chlorine with aqueous sodium bromide.
- 5) Aluminum metal with aqueous copper (II) sulfate.

D. DOUBLE DISPLACEMENT: $AX + BY \rightarrow AY + BX$

- 1) The reaction of aqueous solution of calcium chloride with ammonium carbonate.
- 2) The action of vinegar (dilute acetic acid) on sodium bicarbonate.
- 3) The reaction of hydrogen sulfide on a solution of lead(II) nitrate.
- 4) The reaction of solutions of sodium chloride with silver(I) nitrate.
- 5) The reaction of magnesium chloride with sulfuric acid.

POSTLAB QUESTIONS: Write balanced equations and classify.

1. Calcium reacts with chlorine
2. Sodium chloride is mixed with lead(II) nitrate
3. Sodium reacts with zinc(II) sulfate
4. Diphosphorus pentoxide breaks down into its elements.
5. Metallic aluminum reacts with nickel(II) nitrate