Parent Guide

Unit 3: Reactions

SC3. a Use mathematics and computational thinking to balance chemical reactions (i.e., synthesis, decomposition, single replacement, double replacement, and combustion) and construct an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

For this standard, the students will learn how chemical reactions are written in the form of chemical equations. All of the substances that are undergoing a chemical reaction (reactants) are written to the left and separated by "+" signs. An arrow sign, "→" is used to show that these are chemically being transformed into products, which are also then separated by "+" signs.

Chemical Equation:

$$\underbrace{2\ H_{2(g)} + O_{2(g)}}_{\text{Reactants}} \rightarrow \underbrace{2\ H_2O(l)}_{\text{Product(s)}}$$

Students will then learn how to balance chemical equations, a process that uses coefficients to make the number and type of atoms on the reactant side equal to the number and type of atoms on the product side. Balanced equations are given with coefficients in the least whole number ratio. In this process, the subscripts and formulas for the substances in the chemical equation cannot be changed.

Common errors in balancing equations are as follows:

Breaking up substances to write a coefficient in the center:

Given $H_2O(l)$	$H_2\underline{2}O(l)$	vs.	$2\ H_2O(l)$
	Not allowed		*Allowed*

AND

Failing to apply the coefficient to all atoms in that substance:

$2\ H_2O(l)$	vs.	$2\ H_2O(l)$
H: 4 atoms		H: 4 atoms
O: 1 atom		O: 2 atoms
Incorrect		*Correct*

Finally, students will learn to predict products of unknown reactions (what are the expected rearrangements of the atoms or ions present in the reactants), based on information they have learned in previous units and the basic types of reactions.

SC3. b. Plan and carry out investigations to determine that a new chemical has formed by identifying indicators of a chemical reaction (specifically precipitate formation, gas evolution, color change, water production, and changes in energy to the system should be investigated).

For this standard, the students will design their own experiments to form new chemicals. They must be able to prove that a new chemical has been formed using observational evidence. Acceptable observations include seeing a precipitate (a solid substance forms when 2 liquid solutions are mixed), seeing gas bubbles, the substance changing color, forming water, or the container feeling very warm or very cold upon performing the proposed reaction. Students should check all procedures with their teacher prior to testing to ensure that no hazardous products might be formed and that all necessary safety precautions are taken.

SC3. c. Use mathematics and computational thinking to apply concepts of the mole and Avogadro's number to conceptualize and calculate: • percent composition • empirical/molecular formulas • mass, moles, and molecules relationships • molar volumes of gases

For this standard, the students will use several constants and ratios to perform a wide variety of calculations. In order to calculate the number of grams, moles, or molecules in a given quantity, students must both learn these constants and ratios as well as recall from previous math/science courses how to perform unit conversions.

For example, to determine the molar mass of C6H12O6:

C (carbon) = 12.01 g/mol (from P. Table) x 6 (subscript) = 72.06 g/mol
H (hydrogen) = 1.01 g/mol (from P. Table) x 12 (subscript) = 12.12 g/mol
O (oxygen) = 16.00 g/mol (from P. Table) x 6 (subscript) <u>= 96.00 g/mol</u>
Molar mass = 180.18 g/mol (total)

Dimensional analysis is often used to teach unit conversions. The key to this approach is to consistently write units next to each number while working a problem, as failure to do so leads to unnecessary confusion. A unit can only "cancel out" if it is divided; multiplied units will not cancel out.

The concepts of percent composition and empirical & molecular formulas both rely on a student's ability to correctly convert units as shown above. The percent composition tells what percentage of a compound's mass comes from each element in that compound. To calculate it, one would follow the formula:

$$\%elementA = \frac{Mass\_elementA\_including\_subscript}{Molar\_mass\_of\_compound} x100\%$$

In order to calculate a molecular formula, you are given the molecular weight of the unknown compound. Comparing the weight of the calculated empirical formula to the known molecular weight of the compound will allow the scientist to determine exactly what the new formula is. See the example below for the math behind this method:

"If an empirical formula was calculated to be CH_2O and the unknown compound's molecular weight is 90.09 g/mol, what is the molecular formula?"

1. Calculate the mass of the empirical formula:

C: 1 x 12.01g/mol = 12.01 g/mol
H: 2 x 1.01 g/mol = 2.02 g/mol
O: 1 x 16.00 g/mol = <u>16.00 g/mol</u>
= 30.03 g/mol (CH_2O)

2. Compare this amount to the molecular weight. What would you multiply the empirical mass by to equal the molecular weight?

30.03 g/mol (empirical) vs. 90.09 g/mol (molecular)
Multiply by a factor of 3

3. Multiply all of the subscripts in the empirical formula by this factor:

$CH_2O \rightarrow C_{1x3}H_{2x3}O_{1x3}$ = **$C_3H_6O_3$ (molecular formula)**

SC3. d. Use mathematics and computational thinking to identify and solve different types of reaction stoichiometry problems (i.e., mass to moles, mass to mass, moles to moles, and percent yield) using significant figures. (Clarification statement for elements c and d: Emphasis is on use of mole ratios to compare quantities of reactants or products and on assessing students' use of mathematical thinking and is not on memorization and rote application of problem-solving techniques.)

A stoichiometry calculation allows you to predict how much of each product you will form from any reaction based on your reactant amount(s). This then allows labs and manufacturers to calculate their percent yield, which is used to evaluate the efficiency and cost-effectiveness of various methods of producing the same product.

The main idea behind stoichiometry is that the coefficients used to balance the chemical equation give you the ratio, or recipe, to the chemical reaction. This allows you to convert or predict the amount of any substance in the reaction from just one known reactant. Students sometimes struggle with stoichiometry calculations because they fail to keep track of their units or do not understand the concept of ratios. Please remind your child to write the unit and chemical substance next to every number in every single step of their work, as this will eliminate the majority of mistakes.

Once you have predicted the amount of product, an actual experiment could be conducted, and the final amount of product can be weighed. In order to determine whether the actual amount produced in the lab is "close enough' to the predicted amount, a percent yield calculation is done, yielding a result very similar to a score on a test or quiz. The percent yield equation is:

$$Percent\ Yield = \frac{ActualYield}{TheoreticalYield} x\ 100\%$$

The actual yield refers to the amount weighed in a lab experiment, whereas the theoretical yield is your calculated answer based on stoichiometry.

SC3. e. Plan and carry out an investigation to demonstrate the conceptual principle of limiting reactants.

True stoichiometry involves knowing how much of *each* reactant you are combining to do a particular reaction. As in cooking, if you do not carefully measure out the amounts of each ingredient based on your recipe, in chemistry, if you did not precisely calculate and measure each reactant based on the balanced reaction, then you will have too much of one ingredient (excess reactant), which will negatively affect your final product. The ingredient, or reactant, that runs out first in a chemical reaction is called the limiting reactant.