A Laboratory Experiment Using Molecular Models for an Introductory Chemistry Class

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The use of molecular models goes back to the middle of the 19th century *(1)*. Since then the use of molecular models has become an increasingly popular tool in both teaching *(2–12)* and research *(13)*. The use of molecular models has been exceptionally beneficial in organic chemistry and biochemistry *(5–11)*. And with no exception in every general chemistry laboratory manual there is an experiment using molecular models to study the geometry of organic molecules. Models help students visualize the molecular geometry of a molecule and to conceptualize a particular nature, physical and chemical, of that molecule. Today there are varieties of molecular models available commercially as well as inexpensive homemade ones *(14–22)*.

Table 1. Color Codes for Atoms

Atom	Color
Carbon	Black
Hydrogen	Light blue
Oxygen	Red
Nitrogen	Dark blue

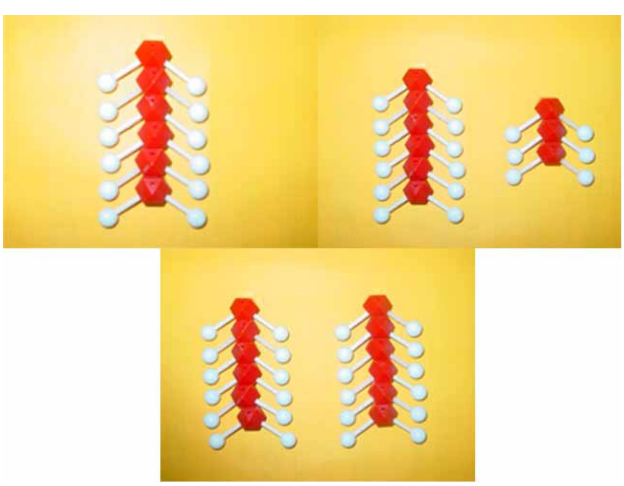


Figure 1. Examples of six-packed or combination of six-packed and individual models of H_2O.

Table 2. Combinations of Six-Packed and Individual Molecular Models

No. of Models	No. of Moles	Mass/g
6 (1 pack)	1	
9 (1.5 packs)	1.5	
12 (2 packs)	2	
18 (3 packs)	3	

Although models have been used to show chemical reactions at molecular level *(23)*, they have not been used to the extent presented in this article. A different approach is presented that uses molecular models as a learning aid, either in the classroom or in a laboratory setting, to teach basic concepts in general chemistry. The students' response was very positive. They could easily make the connection between working with models and related concepts, and they became actively engaged in their learning process.

General Procedure

Each group of students is given two sets of molecular models[1] and instructed to use the color codes given in Table 1.[2] To help students construct the molecules properly molecular formulas are used in the chemical equations.

Mole Concept

Students make three sets of six models of H_2O molecules (or any other simple molecule). A set of the six models are packed together with a rubber band to hold them together. A set of six-packed molecular models represents a mole. This will help students have a visual aid and also be able to count the number of pieces to answer related questions. By using the six-packed sets students can answer questions such as (i) how many molecules of H_2O are there in 1, 1.5, or 2 moles of H_2O? (Figure 1) (ii) how many moles of H_2O are 9, 12, or 15 molecules of H_2O? or (iii) how many atoms of hydrogen are there in 0.5, 1, or 2 moles of H_2O?

Molar Mass

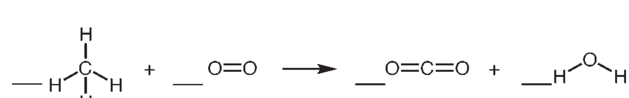
The mass of a set of six-packed molecules (one mole) is measured. This represents the molar mass of the chemical substance. Then a different number of six-packed or any combination of six-packed and individual molecular models, such as ones in Table 2, are weighed and tabulated.

Balancing Chemical Equations

To help students to conceptualize the basic principles of balancing chemical equations a simple unbalanced chemical equation such as the following is used:

$$\_\_CH_4 \;+\; \_\_O_2 \longrightarrow \_\_CO_2 \;+\; \_\_H_2O$$

To help students the structural formulas can be given as well:



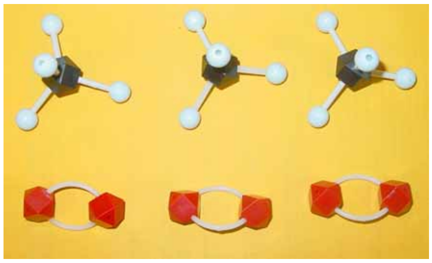


Figure 2. Three sets of CH_4 and O_2 models.

Table 3. Number of Reactants and Products

Reactants		Products	
Compound	Number	Compound	Number
CH_4	1	CO_2	1
O_2	2	H_2O	2

Each group of students makes three sets of CH_4 and O_2 models (Figure 2). Students start with only one model of CH_4 and one of O_2 to make models of CO_2 and H_2O. After two H_2O molecular models are constructed using parts from the CH_4 and O_2 models, students realize that there are not enough oxygen atoms to make the CO_2 model. At this point, they are allowed to use another O_2 model as long as they record the number of each model they use in a table such as Table 3. With the one carbon atom left and the second O_2 model they are able to make a model of CO_2 (Figure 3). Now, the students should be able to balance the chemical equation by writing the number of each model used or made (from Table 3) in front of its corresponding molecule in the unbalanced equation:

$$CH_4 \quad + \quad 2O_2 \longrightarrow CO_2 \quad + \quad 2H_2O$$

To enforce the balancing concept, students place one model of CH_4 and two models of O_2 on one side of their desk or work bench and one model of CO_2 and two models of H_2O on the other side and count number of colored pieces on each. They should have the same number of black, red, and light blue pieces on both sides.

Bonds Breaking and Bonds Forming

The same procedure can be used with emphasis on the kind and the number of bonds that are breaking and forming and compare number of bonds on both sides.

Conservation of Mass

To emphasize the importance of balancing chemical equations and demonstrating the law of conservation of mass, students measure the mass of one model of CH_4 along with one O_2, and one molecular model of CO_2 and one H_2O together (Figure 4), and record their data in a table such as Table 4.

Next, they weigh CH_4 and O_2 together and CO_2 and H_2O together, except this time they use the correct number of each model as indicated in the balanced chemical equation (Figure 5). The difference between the masses of the products and the reactants for each case is calculated and recorded in the table. The results clearly demonstrate the law of conservation of mass in a balanced chemical equation.

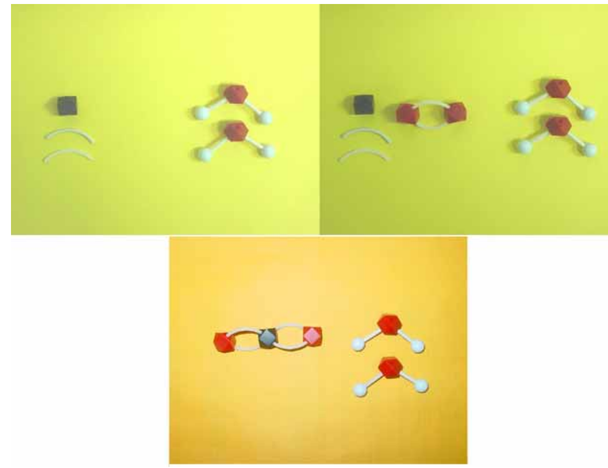


Figure 3. With an additional O_2 molecule the students are able to make a model of CO_2.

After students have a good understanding of mole, molecule, and molar mass they are instructed, instead of using six for the number of particles in one mole, to use Avogadro's number.

Figure 4. Weighing the incorrect number of molecules.

Table 4. Mass of Different Molecules

	Mass/g		
Equation	CH_4 + O_2	CO_2 + H_2O	Difference
Unbalanced	8.238	8.896	0.658
Balanced	11.928	11.926	0.002

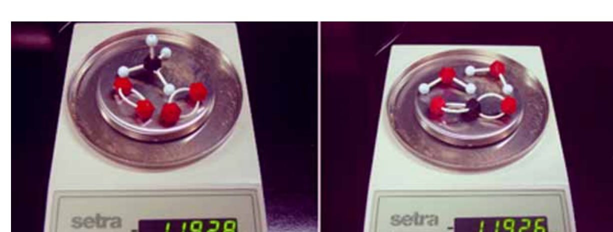


Figure 5. Weighing the correct number of molecules.

Students can repeat these procedures using other unbalanced chemical equation such as,

$$\_\_\_N_2 + \_\_\_H_2 \longrightarrow \_\_\_NH_3$$

$$\_\_\_C_2H_6 + \_\_\_O_2 \longrightarrow \_\_\_CO_2 + \_\_\_H_2O$$

Limiting Reactant Concept

The molecular models can be used to demonstrate limiting reactant concept. The approach is very similar to balancing equations. Students are given a certain number of each type of reactant molecule and are asked to make the products. Soon they will realize that there will be some leftover of one of the reactants.

[W]Supplemental Material

Instructions for the students including pre- and postlab questions are available in this issue of *JCE Online*.

Notes

1. Molecular Structural Models for Organic Chemistry from Benjamin/Maruzen HGS were used (Maruzen International Co., Ltd., 1200 Harbor Blvd., 10th floor, Weehawken, NJ 07086).
2. Make sure that parts used for different elements have different masses. For example pieces for oxygen are different from pieces used for carbon.

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