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A Speed of One Molar Per Second Presents Some Blocks In the Road

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Abstract

It is challenging for students in general chemistry to recognize that every chemical reaction is associated with a rate (speed). Peer Leaders in second semester general chemistry have found a 'solution': provide students in Workshop with oversized Lego®-like blocks in a large clear bag. These blocks can be used to represent molecules composed of atoms with appropriate combining properties. The blocks permit visualization of amounts of reactants and products in a chemical reaction like 1) H_2 and O_2 to produce H_2O (burning of hydrogen) or 2) CH_4 and O_2 to produce CO_2, and H_2O (combustion of methane). Concentrations of reacting species can be followed as the reaction progresses by having student teams play close attention to the rearranging block combinations over time. Reacting a certain amount (e.g. one molar) of the combustible reactant per unit time can be easily represented to reconcile and visualize the abstract concept of "rate of a chemical reaction". Moreover, altering the starting 'concentrations' of reactants (differing initial numbers of block combinations) permits students to understand two difficult concepts: limiting reagent and final concentrations at completion or at equilibrium. The 'blocks' transform an obstacle into a vehicle for students to 'get' the speed of reaction.

Introduction

When students encounter the second semester of general chemistry, they begin to realize something they had believed for at least a semester: reactions don't simply happen by magic at the instant you mix two reactants. However, it becomes hard for them to appreciate that there are little "particles" (the ones we call molecules) that are bumping into each other and beginning to react. Moreover it becomes very difficult for them to understand that it takes time for two "particles" to meet in the proper way and in the proper amount. Chemistry takes time.

In the second semester course, students start developing questions like "how does one molecule react with something else?" or " are the electrons still moving when they are in bonds?" or "how do molecules interact if their electrons meet somehow?" Gaining a sound understanding about molecular interactions is difficult to obtain. Keeping track of the progress of a reaction presents most students with many troubles. As the topic of chemical kinetics approaches, students have forgotten (or never really appreciated) the conservation of matter. A simple way is needed to allow the students to grasp relative combining amounts based on reaction stoichiometry then relate the speed of a reaction to the changing amounts of each reactant and each product. The problem is all the more acute when the coefficients are not 1 and 1 and 1.

Results and Discussion

A simple solution is to use Lego®-like blocks as a teaching tool to help students grasp amounts of reactants and products during the kinetic course of reaction. Previously Lego® blocks have been used to explain stoichiometry in chemical reactions (Witzel, 2002), keeping a laboratory notebook (Pendley, 2001), and understanding the structure and functionality of a microscope (Campbell et al, 2011) A new use of Lego®-like blocks builds on the stoichiometry use of Wirzel by taking advantage of the combining properties made possible by this kind of toy. Student-teams receive large plastic bags (e.g. 4-gallon Ziplock® bags (Figure 1) containing sets of different color large Lego®-like blocks.

Figure 1. Ziplock® Big Bags used to represent the 'Reaction Chamber'.

The large size of the blocks is preferable to actual Lego® blocks because the large size dissuades students from playing with the blocks in Workshop instead of using them for the intended purpose. Regular Lego® blocks seem to distract from the chemistry. The essential feature of the blocks is their combining capability. This means they must have 1, 2, 3, 4, etc bumps and depressions (Figure 2) in order to appropriately represent the combining properties of the atoms specific to a reaction being examined. For example, blocks with one bump and one depression represent the correct combining properties for hydrogen atoms; blocks with two bumps and two depressions have appropriate combining properties (for this exercise) for oxygen; (blocks with four have appropriate combining properties for carbon; three for nitrogen); etc. If the team puts four one-bump blocks into a single four-bump block, the assembled unit will consist of the appropriate number and character of atoms to represent a molecule of methane.

The first activity challenge should involve familiarization with the blocks to depict atoms and molecules. Peer leaders in peer-led team learning (PLTL) (Gosser and Roth, 1998; Gosser et al, 2001) workshops should provide instruction to the effect: "Use blocks with one bump/depression and other blocks with two bumps/depressions to assemble hydrogen molecules, oxygen molecules, and water molecules. In teams, choose which blocks best represent assemblages with appropriate characteristics of each kind of molecule." A first reaction to examine might well be the burning of hydrogen gas to yield water. This is such a simple, yet important reaction to illustrate the use of the blocks and also involves a stoichiometry with nonunitary coefficients. "Use the blocks in the bags to assemble as many hydrogen molecules and as many oxygen molecules as possible." (A suggestion is to start with all bags having the same initial numbers of the two types of atoms, perhaps eight atoms of each.) "Now form as much water as possible with the assemblages you have available."

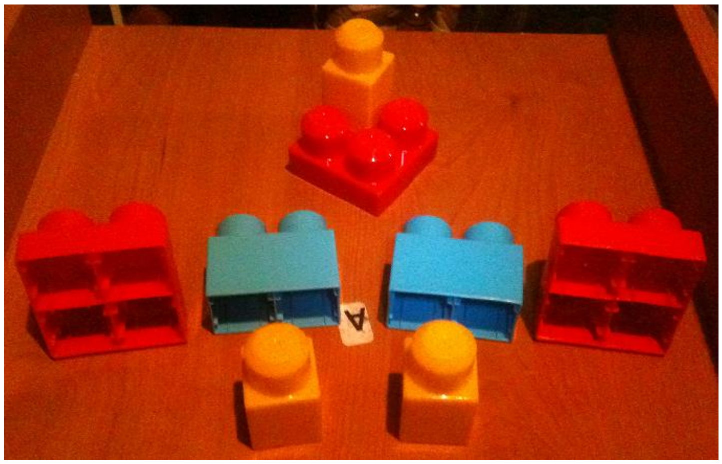

Figure 2. Colored large Lego®-like blocks with appropriate combining properties

Students need practice getting used to blocks as representations of atoms of elements. This takes time and activities that build on one another may well need to be repeated in more than one workshop session to get the point across. After this initial familiarization, the explanation of progress of reaction and its relationship to rate of reaction can be considered.

A slightly more complicated, yet still simple reaction, is the combustion of methane to produce carbon dioxide and water. A sample Worksheet for this Exploration (Becvar, et al, 2003; Becvar, 2004; Frederick and Becvar, 2009; Campos-Flores, et al, 2010; Ronquillo, et al, 2010; Becvar, et al 2012a; Becvar, et al 2012b) is shown in Figure 3. This reaction will require blocks with four-bumps/depressions to represent carbon, one-bump/depression blocks for hydrogen, and two-bump/depression blocks to represent oxygen.

You Blockhead!! (An Exploration)

There are five bags. In each bag you will find block assemblages. Do not take them apart!! Do not play with the blocks, you blockhead!

Some block assemblages represent CH_4 molecules; some block assemblages represent O_2 molecules. Don't disassemble, but determine which assemblage must be which. The unbalanced chemical reaction is:

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

Write the balanced equation. Use your balanced equation as follows.

Assume each bag represents a 'reactor', but each bag has a different starting composition of the two reactants, i.e. different numbers of CH_4 and O_2 molecules. Don't disassemble!!! Based on what CH_4 looks like (the relative numbers of bumps, etc) and what O_2 looks like, think about how to use your blocks to represent CO_2 and H_2O. What will those look like?

Do not 'partially' react CH_4 or O_2 (e.g. to leave CH_2 or O, and do not make CO or HO etc). Make as many CO_2 and H_2O molecules as you can with the blocks available based on the balanced chemical equation.

Now think about each assemblage as representing one mole of molecules instead of one molecule. What mass of each reactant did you start with in your bag, what mass of each product did you end up with? What is the limiting reagent for your bag? What is left over? Prepare a table showing amounts of each reactant at the start and each substance after reaction as far as possible.

Now make the assumption that the volume of the bag is 10.0 L. How many moles of each substance did you start with? If the volume is 10.0 L, what molar concentration of each substance did you start with? What were the concentrations of all substances at the 'end' of the reaction?

Now prepare another table listing: time, $[CH_4]$, $[O_2]$, $[CO_2]$, and $[H_2O]$. At time zero, show t = 0, $[CH_4]_0 = x$, $[O_2]_0 = y$, $[CO_2]_0 = z$, and $[H_2O]_0 = etc$, where x, y, z, etc are the values for your bag of molecules (z and etc should be 0 if no products are present at t = 0!). At t = 1, allow one "reaction's worth" of reactants to form products. (at t = 1, z

= 1; $etc = 2$) and so on. Fill in the table until the limiting reagent is 'used up'. Now plot [ ]'s versus time for all substances in the 10.0 L reactor.

<u>Extensions</u>

Now write up the reaction based on masses of each reactant. Challenge yourself to perform the calculations necessary to determine the limiting reagent, the maximum mass of each product you could make based on your starting masses of reactants.

Figure 3. A worksheet for the 'You Blockhead!' Exploration

Before Workshop, leaders should assemble as many bags as there are teams in Workshop. Have the student teams start by assembling as much methane (one four-peak block with four one-peak hydrogen blocks) and as much oxygen (two two-peak blocks together) as possible from the starting composition of atoms. Then consider each piece as a mole and consider a convenient volume for the bag such as 10.0 L. For example if there are eight methane blocks then the concentration for methane will be 0.8 M at time = 0. However, the number of moles of each reactant at the initial time is up to the peer leader. A good variation would be to conduct the exercise several times with different combinations of starting 'concentrations'.

The next step would be to decide time increments and how many moles of each reactant will react in each time increment (for obvious reasons, these have to be in integers). Every student in each team should construct a table of data. Table 1 shows sample values for initial concentrations of reactants and products along with the initial change in [CH_4] making the assumption that one mole of methane reacted in that first time increment (as shown in Table 1).

Table 1. Partial data table for the 'You Blockhead' Exploration

Time	[CH_4]	[O_2]	[CO_2]	[H_2O]
0	0.8	1.0	0	0
1	0.7			
2				
3				
4				

Today's students have great difficulty with graphing and scaling data within the graphs. This is a very good exercise for this purpose. For example, if students are challenged to depict time points such as 0, 1, 2, 4, and 8 on a linear scale, many will show the increment size between 1 and 2 as identical to that between 2 and 4 and between 4 and 10. Dealing with increments along the ordinate axis (how many of today's students of science know what that means?) presents even greater difficulty.

The Exploration activity should conclude with graphing of the data. For convenience, initial graphs may have equal intervals of time. However, peer leaders may want to use this activity as a lead-in to plotting concentration versus time for many other reactions, especially those depicting first-order or second-order behavior. This activity gives ample practice with concentration versus time consideration for reactions. The concept of 'Limiting Reagent' should become more apparent to students. The relationship of slope of the curves to rate of chemical reaction must be included in this activity. Simple extensions considering important concepts such as half-lives, half-times, should be made. Finally, the use of these blocks can be extended to consideration of equilibrium at the appropriate time in the course.

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