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VISUAL REPRESENTATION OF MATTER AIDS UNDERSTANDING OF CHEMICAL KINETICS

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For second semester General Chemistry classes at the University of Texas at El Paso, students must plot and understand Concentration vs. Time graphs for substances during kinetic processes. Many students are not able to conceptualize the conservation of mass under constant volume conditions and are thus unable to rationalize concentration changes during chemical reactions. The use of shapes (e.g. triangles, circles, squares) to represent different atoms in molecules, aids comprehension of chemical kinetics during Peer-Led Team Learning Workshop. Pictorial representation of atoms using fixed numbers of specific shapes helps students visualize the conservation of matter in chemical reactions. Reactions start and end with the same number of atoms as the reaction progresses from reactants to products. Through this visual interpretation students can see which compound is the limiting reagent, how much of the other reactant is left over, and how much product can be made.

Chemical kinetics

According to Chang (10th edition), "[Chemical Kinetics] refers to the rate of reaction… which is the change in the concentrations of a reactant or a product with time (M/s)" (p. 558). Another thing to keep in mind when we discuss chemical kinetics is that the reaction is going to completion, meaning you will run out of at least one reactant and create as much product as possible. The reactant you run out of first is called your limiting reagent. The limiting reagent is what will determine how much product you can make.

In the case of where one reactant yields one product, we have the reaction R → P. For this, R is our limiting reagent and P is our product. While we can't determine the rate of this reaction without more details, we can state how the rates of the reactant and product relate to each other. Rate is equal to the change in concentration over time or Rate = Δ M/t. In this case for every one molar concentration (mol/L) of reactant lost there is a gain of one molar concentration of product. This can be shown as Rate = $-\Delta$ [R]/t = Δ [P]/t for this reaction; for the reaction R → 2P. Here for every one molar concentration of reactants lost, there is a gain of two molar concentrations of product. This means that the rate of the reactants is only half as fast as the rate of the products, which we can represent as $-\Delta$ [R]/t = ½ (Δ [P]/t). For the reaction 2R → P it would be the reverse of the previous situation, because we are losing two molar concentrations of reactant for every one molar concentration of product produced. In this case, we would represent how the rates relate as – ½ Δ [R]/t = Δ [P]/t.

Concentration versus time

Another way to represent the relation of reaction rates is in using a concentration versus time graph. In Chang 10th edition, students are given the graph in Figure 1 (p. 559). This is a molecules versus time graph of A → B. Since the reaction is a one to one stoichiometry, the rates of reactant and product are equal with the reactant rate being negative to show a loss of moles. The curve on the graph shows that as the reaction proceeds to completion, the rate of the reaction slows down. Even if we cannot determine the exact rate of reaction from the graph, we can determine that both reactant and product rates decrease equally in molecules per second. While this graph is in molecules, we can convert to get a concentration versus time graph.

Figure 1

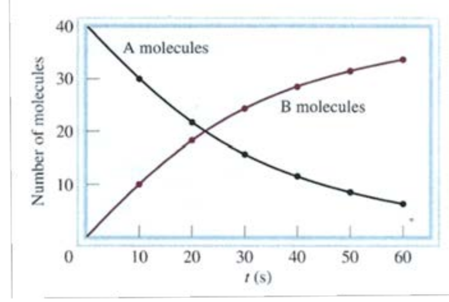
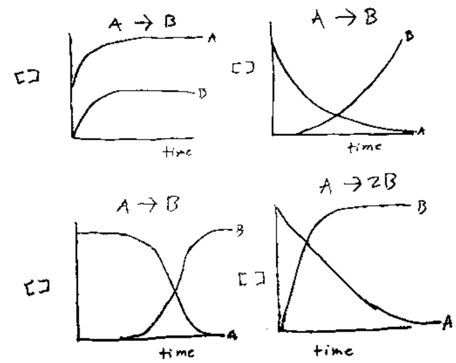


Figure 2

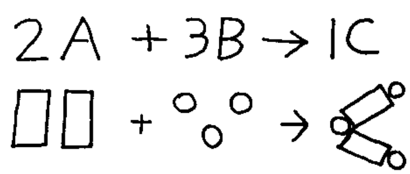


Instillation in workshop

Even with the material above explained in the textbook and from lectures, many students are still unable to create a concentration versus time graph correctly. This is where peer-led team learning workshops help students practice and apply what they have learned in lectures. One factor that was determined as to why the students were unable to complete the task correctly was because they lacked the ability to conceptualize conservation of mass under constant volume. Students would form curves on the graph that would create end results with extra or less concentrations, or within the curves have amounts of concentration appear or disappear.

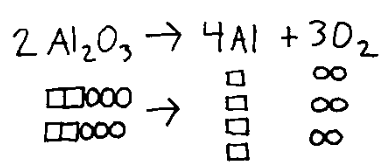
Typical student errors are shown in Figure 2. If students are unable to create the graphs correctly, then they are unable to answer further questions about the limiting reagent, leftover reagent(s), or the amounts of product(s) produced.

Figure 3



It is important for students to understand what a reaction equation is stating. In Figure 3, the reaction is 2A + 3B → 1C. From this it is known that it takes two moles of A and three moles of B to make one mole of C. We have not destroyed any matter but rather rearranged it to form a new compound. For reactions with more complicated compounds, we may need to see every element involved such as in Figure 4 where we are taking aluminum trioxide and creating aluminum and oxygen. Aluminum is represented by squares and oxygen is represented by circles. If we look at both sides of the reaction (reactants and products) we will see that

Figure 4

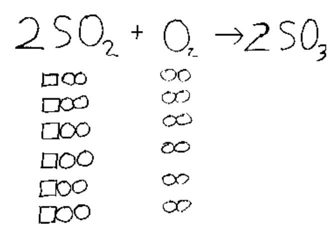


we have equal amounts of oxygen and aluminum. This shows that there is no new creation or elimination of matter, but just a rearrangement into products.

So how could we apply this method to a problem? For example, let's say we have 6M of sulfur dioxide and 6M of oxygen in order to create sulfur trioxide. Using this reaction $2\ SO_2 + O_2 \rightarrow 2\ SO_3$, state how much product can be made, identify the limiting reagent, and how much of the other reagent is left over. Also draw a concentration versus time graph.

Step 1. Write down the reaction (Figure 5).

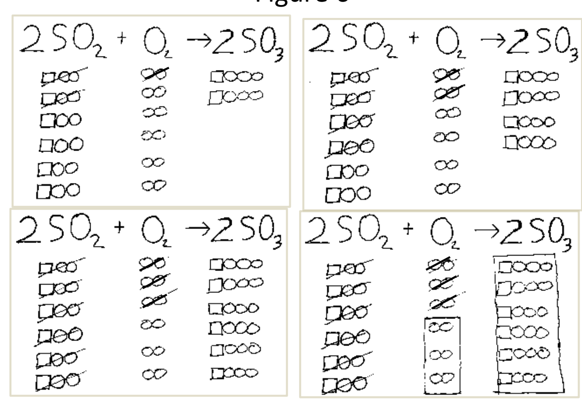
Figure 5



Step 2. Choose the shapes of your elements. In this case, let's go with squares for sulfur and circles for oxygen.

Step 3. Draw the amount of molarity you have where each compound you draw represents one molar concentration.

Figure 6



Step 4. Complete the reaction one time, and show the used reactants and how much product is produced (Figure 6).

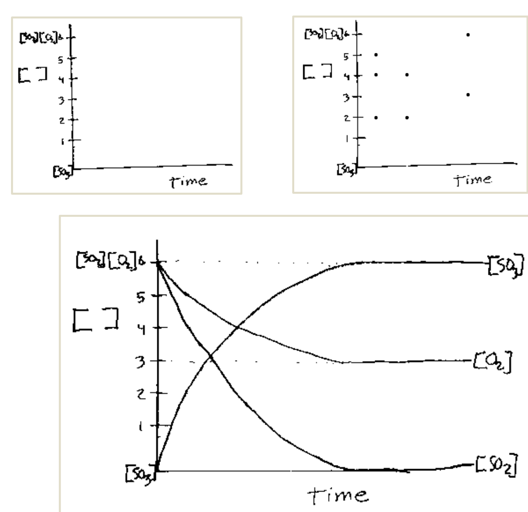
Step 5. Repeat step 4 until you run out of a reactant. Be aware that the reactant which runs out first is you limiting reagent.

Step 6. Enclose in a box any reactant leftover and product created at the end of the reaction.

Step 7. Begin to draw the graph by labeling the axis as shown (Figure 7).

Step 8. Label the y-axis where your reactants and product begin (Hint: We had no product in the beginning).

Figure 7



Step 9. Show the changes in concentration of each compound from the first time you completed step 4 by placing dots on the graph at a time.

Step 10. Repeat for each time you completed step 4, keeping in mind to increase the gap between the times it took to reach those concentrations, because as stated before, the rate of reaction continues to slow down as the reaction moves towards completion.

Step 11. Connect the dots to form a curved line for each different compound.

Step 12. Label the final concentration of each compound.

By having the correct graph, the students can then see how the rates of each compound relate to each other at any given point and that conservation of matter is applied throughout the whole reaction.

Peer Leaders can then give students more practice in understanding the relation between rates by changing concentrations, adding product at the beginning of the reaction, asking students to change the concentration so neither reactant is present at the end of a reaction, and asking what is present at the half-time of the reaction.

An enhancement that can be made to the activity is to use building blocks or molecular kits to represent the compounds. By doing this, the students are able to physically break the reactants and create the products (Figure 8).

<u>Review of previous and preparation of future material</u>

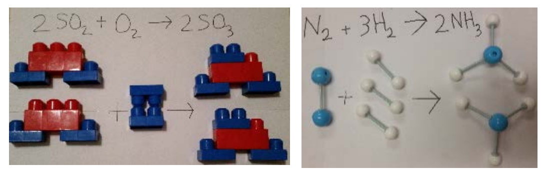


Figure 8

By completing the above activity students are able to review material previously learned in general Chemistry 1, which include balancing equations, stoichiometry, and concentration. They are also able to review molecular geometry and hybridization material if molecular kits or Lewis structures are included. By helping students understand the conservation of mass and reaction rates, Peer Leaders are better preparing them for future material in equilibrium and Organic Chemistry.

<u>Acknowledgements</u>

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<u>Reference</u>

Chang, R. (2010). *Chemistry* 10th edition. New York, NY : McGraw-Hill

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