Visualizing Chemical

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One of the reasons some students never really get started in chemistry is because they fail to grasp the notation used for reactions. Those funny symbols surrounded by large and small numbers seem like a foreign language and their connection to atoms is hard to grasp. If a student is stumped by chemical reactions, too often the teacher will emphasize the symbols and how to balance an equation, without really addressing the source of student confusion. More likely, a stymied student fails to understand that the reaction equation summarizes a rearrangement of a few atoms that is repeated many, many times.

Focusing on atoms and their interactions is a powerful way to overcome these problems. Once students understand a reaction for a representative group of atoms, then the notation used for standard chemical reactions begins to make sense.

The *Science of Atoms and Molecules* (SAM) project at the Concord Consortium is designed to provide just such an atomic perspective across the secondary curriculum. SAM is developing 24 activities that can be used in introductory physics, chemistry, and biology courses. SAM activities introduce a coherent collection of ideas about the properties of atoms and molecules that provide explanations for many phenomena that otherwise must be taken on faith and memorized. For instance, "Chemical Reactions" addresses chemical reactions at the atomic scale using the powerful Molecular Workbench system.

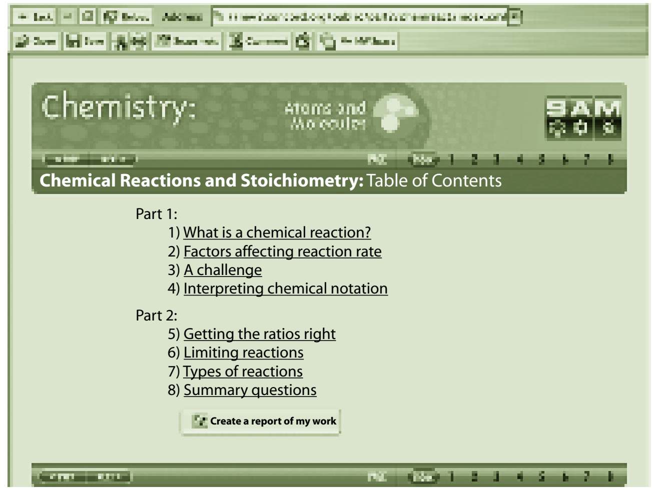

Figure 1. Molecular Workbench opens in a special "browser."

Getting started

Open Chemical Reactions at:

www.concord.org/resources

For more information about Molecular Workbench, click on the "home" icon, which looks like a house, in the Molecular Workbench browser command bar. For a database of hundreds of activities that use Molecular Workbench, use your regular Web browser to access *http://molo.concord.org*.

Part 1: Chemical reactions and a challenge

The unit consists of eight activities that are linked from an index page (see figure 1). Have students become familiar with chemical reactions and how they are influenced by temperature and concentration by going through the first two activities. Then ask students to complete the short challenge based on this introductory material.

Students start with ten separate atoms, which begin to join together as molecules as

Technical help

Molecular Workbench requires several megabytes because it provides a sophisticated computational model that closely matches how atoms and molecules interact and react. The software also supports editing, authoring, and delivering the materials.

The first time you launch the Chemical Reactions activity it will take some time, but subsequent launches from the same computer will be fast, since Molecular Workbench and this activity are automatically cached.

If you do not see the index page (shown in figure 1) after a short delay, go to *http://mw.concord.org/modeler/* for help. The most likely problems involve the version of Java you have, local firewalls, and security precautions.

It is well worth the wait to download!

Reactions One Step at a Time

LINKS *Friday's Lesson*

Science of Atoms and Molecules
http://sam.concord.org

the temperature is increased. As the simulation runs, pairs of atoms form molecules (see figure 2). The bar on the right shows the percentage of the atoms that are part of molecules. Students must get 80% of the atoms to become part of molecules by increasing or decreasing the temperature of the molecular chamber.

Students discover by direct experimentation with the model that an intermediate temperature is best. Too cold, and the atoms seldom get close enough to react; too hot, and the random motion is so violent that the molecules break apart and 80% completion is rarely achieved.

Part 2: More reactions, plus ratios

In the second part, students experiment with other reactions. One model involves making water from hydrogen and oxygen. Have students select different numbers of molecules of oxygen and hydrogen and watch what happens. If they select two molecules of hydrogen and one of oxygen, they will observe the sequence of steps that follow, starting with figure 3 (A).

1. The oxygen breaks into atoms and then one of the hydrogen atoms exchanges its partner for a free oxygen (B).
2. Later (C), the other hydrogen finds the other free oxygen, creating two OH radicals.
3. After a long time (D), the hydrogen molecule breaks apart.
4. Soon (E), one free hydrogen finds an OH to make one molecule of water.
5. A bit later (F), the reaction is complete, with two water molecules.

Note: To get a sense of the relative time of each step, notice the clock measured in femtoseconds (fs) in the lower left of each screenshot. One femtosecond is 10^{-15} seconds.

The details of the partial reactions are not as important as the fact that the overall reaction $2H_2 + O_2 \leftrightarrow 2H_2O$ involves several steps that rearrange the atoms. Thus, the overall reaction hides a lot of details of what actually happens to atoms. When students look carefully, it is clear that no atoms disappear or are created. It is also clear that a sequence of simple events happens at random and requires the right temperature.

Assessment

Like all our SAM activities, this one includes embedded student assessments.

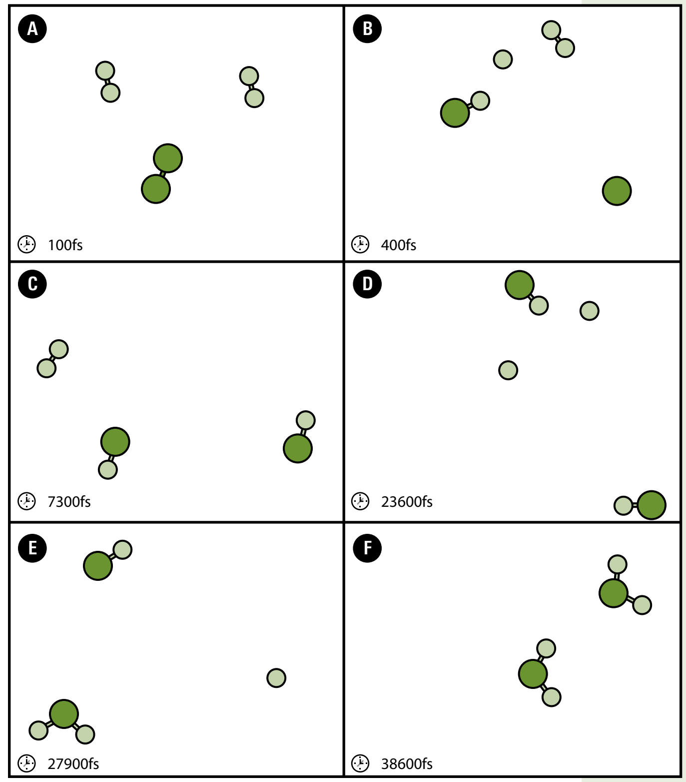

Figure 3. Six frames from the simulation that forms water. The larger atoms are oxygen and the smaller are hydrogen.

Almost every page has a few questions in either multiple-choice or open response form. The multiple-choice questions are intended for self-testing and have a "Check Answer" option. In addition, the final activity has both types of question, but no way for students to check their answers. All student responses and any snapshots they make are collected in an electronic lab book. Students can draw from these to make a report.

Use this report writing capacity by giving a specific assignment. For example, you might ask "What is the minimum number of hydrogen molecules that are required to synthesize ammonia (NH_3) by reacting with 300 nitrogen molecules? Explain your reasoning and use evidence from Molecular Workbench models."

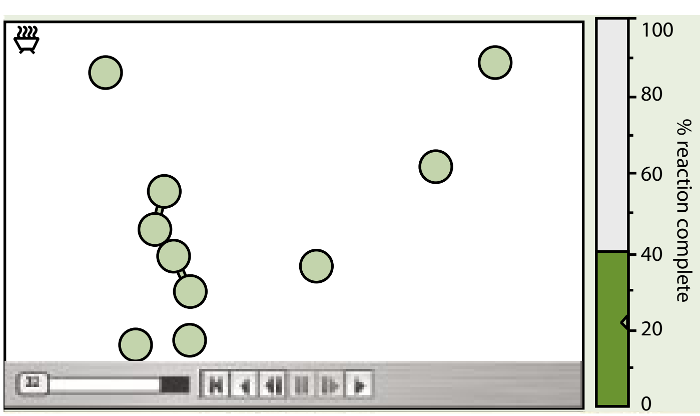

Figure 2. The bar on the right shows the percentage of atoms that have joined as molecules. Students are challenged to reach 80%.

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