Colliding Particles Demonstration: Irene Walsh

Teacher's Guide

Goals

- To relate abstract topics to analogies that students can understand
- To help students visualize the concept of particles reacting

The Demonstration

In this class, students get a feeling of the world of particles and the collisions between them. They use analogies, which illustrate schematically the principles of molecular collisions. These analogies help them imagine and understand how particles collide and the factors which influence their collisions.

Materials

- 5 marbles

Lecture Notes

Write on the blackboard the reaction:

$4HBr + O_2 \rightarrow 2H_2O + 2Br_2$

Identify the reactants (R) and the products (P).

What did we say had to happen in order for a reaction to occur? We need collisions to occur.

How many particles are there on each side? (5R and 4P)

There are five particles colliding.

Demonstration

Call up five students and position them by a "demonstration table" (a higher table, if possible). Give each student a marble. Ask them to try to make all five marbles collide simultaneously, to get the feeling of the colliding particles in the reaction discussed. Try it several times. Collect the marbles.

Ask the students: What do you think that the probability is of this simultaneous collision happening? Very low.

Addition

Emphasize that this is a complex reaction and, like many others, follows a complex mechanism that comprises several steps. In each step only several particles collide, and thus the collision probability is higher (and depends on several other factors such as molecular geometry and electron distribution).

The actual mechanism of this reaction involves a series of consecutive bi-molecular reactions, thus raising the probability of effective collisions:

$HBr + O_2 \rightarrow HOOBr$

$HOOBr + HBr \rightarrow 2HOBr$

$2HOBr + 2HBr \rightarrow 2H_2O + 2Br_2$

And the overall reaction is:

$$4HBr + O_2 \rightarrow 2H_2O + 2Br_2$$

To sum up: this analogy can be used to promote the concept of reaction mechanism, and to describe its importance for chemical reactions.

Teaching Tips From Ms. Walsh

Very often the topics in chemistry are abstract, and we need to relate that to something that the students can understand: something that they can touch with their hands and say that what you're doing is making an analogy. And while you're doing it you want to look for good analogies and then build from there.

I think it is really important that the students visualize that these are particles that are reacting.

If the particles are the things that must collide when they react, when you're teaching, you have to get that idea down first, and then other things make sense.

I sort of likened that to Volkswagens colliding with each other. If you just have a little Volkswagen parked on an incline, and it slides into the other one, ask them to picture that vs. testing these: the car manufacturers having them going 60MPH, smashing into each other, and then I ask them the question:

> In which case do you get a bigger "Volkswagen rearrangement"?

In order for a reaction to occur you've got to get a rearrangement of the particles. The collision has to be that violent. So you get a rearrangement of the particles. That kind of thing is the activated complex, that's going to form. Then we start talking about the energy that is required, the minimum amount of energy, and that's activation energy.

Comment

The "colliding car" analogy serves best to describe the case where the reaction mechanism is: A + B -> AB, and does not directly refer to the role of the activated complex. However, in the reaction, it partially represents the concept of the dependence of rate on the velocity (temperature) of the reacting particles.

It is not simple, however, to find a good single analogy for a full chemical reaction, which represents the colliding reactants, the activated complex (which has a very short life, relatively) and the products. One idea might be to compare the reaction process to baking cookies.

The ingredients being the reactants, the "transition state" will be the dough on the tray just before and during baking, and the products are the cookies. This analogy lacks some important concepts such as vibrational modes of the activated complex, molecular geometry, and probability of collisions. But if you look closely, you still can extract some useful conclusions from it:

First, you put the reactants together (collisions), then, you form a short-lived, unstable, and odd-shaped form of cookie (transition state) and finally you collect the cookies (products).

You may also refer to energy: most reactants and the products are edible (low-energy) and relatively long-lived, whereas the "transition state" cookies are relatively short-lived and will cause a stomachache if eaten (high-energy). Also, to get from reactants to products, you must heat the system and overcome the "activation energy" for the process. Only when the cookies cool off ("stabilize"), can you eat them.

If you want to show the *probability* of a collision, you would need a whole different analogy, which takes into consideration things like cross-section for interaction, velocity, and mass. It is a physical process that might be well visualized just by drawing it on the board or by thinking about colliding (but not reacting) billiard balls.

The *reactivity* of colliding molecules, and the transition state are complex concepts which include concepts like molecular geometry, energy distribution within molecules, and vibrational modes. These concepts should be illustrated one by one, and only then can the whole picture be explained.