Successful Collisions

Introduction

What leads to a successful collision between particles in a chemical reaction? In this demonstration, "particles" will be "collided" to determine the effects of concentration, pressure, number of particles colliding, and collision geometry on the success rate of collisions.

Concepts

- Collision theory
- Reaction rates/mechanisms

Materials

Styrofoam® spheres, about 3″ in diameter, 6
Styrofoam® spheres, about 1″ in diameter, 3
Pins or glue (hot melt glue works well)
Velcro® strips

Safety Precautions

Wear safety glasses and always follow laboratory safety rules when performing demonstrations.

Preparation

Cover about 25% of the surface of one small and one large sphere with Velcro using pins or glue. Cover about 50% of the surface of a second small and large sphere with Velcro using pins or glue. Cover 100% of the surface of the third set of small and large spheres with Velcro using pins or glue. In each set of spheres prepared (25%, 50%, 100%), make sure that one of the spheres is covered with the loop part of the Velcro and the other sphere is covered with the hook part of the Velcro so that they will stick together. Leave three large spheres uncovered.

Procedure

1. Position two student volunteers about 4 meters apart and give them each a large, uncovered sphere. Ask them to toss the spheres so that they collide in mid-air. Discuss the level of difficulty in making a collision. A collision here is defined simply as the balls hitting, but not sticking. Allow the students to move closer together and toss the spheres again. Again, discuss the difficulty in making a collision. Relate the frequency of collisions to the concepts of concentration and pressure.
2. Choose one more student volunteer. Give this student a large, uncovered sphere, and ask her to join the first two students. Ask them to toss the spheres to produce a three-way collision. In this case, all three spheres must hit simultaneously to say a collision has occurred. Discuss the level of difficulty in making a collision. Relate the frequency of collisions to the probability of three-body collisions occurring and reaction mechanisms.
3. Choose two more student volunteers and give them the set of fully covered spheres. Explain that the Velcro represents an active site for the occurrence of a successful collision and bonding. Have them stand about 1 meter apart and toss the spheres to produce a collision. Now a collision involves the balls not only colliding, but also sticking together. Compare the collisions produced in this case with those produced in the first two examples. Note that almost all of these collisions are successful. Repeat this procedure with other pairs of students and the partially covered sets of spheres. Discuss the results and relate them to the concept of collision geometry.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter

Publication No. 10214
061616

Content Standards: Grades 9–12

Content Standard A: Science as Inquiry

Content Standard B: Physical Science, structure of atoms, structure and properties of matter, chemical reactions, motions and forces, conservation of energy and increase in disorder, interactions of energy and matter

Discussion

A successful collision between reactants in a reaction system is a collision where molecules not only collide, but also form an activated complex that then goes on to form products. Concentration, pressure, and the number of particles colliding affect the number of collisions that occur per unit time. These factors, plus the collision geometry, then determine if a collision will be successful. The frequency at which successful collisions occur determines the rate of the chemical reaction.

Concentration/Pressure. Increasing the concentration or pressure of reactant molecules increases the number of molecules in a given area. As molecules move, they are more likely to collide with other molecules simply because the molecules are more densely packed. The same fraction of collisions will produce products, but because more collisions are occuring overall, a higher number of successful collisions will occur.

Reaction Mechanism/Number of Particles Colliding. For three particles to collide, three reactants must be in exactly the same place at the same time. The probability of this occurring is less than for just two particles to be in exactly the same place at the same time. Therefore, if an overall reaction contains three reactants, the reactants most likely combine in steps—a reaction mechanism—that consist of smaller reactions between only two particles.

Collision Geometry. In a reaction system, the spatial orientation of reactants must be such that it allows the formation of new bonds in the activated complex to begin. Many collisions may occur, but only those that collide with the correct orientation will produce a successful collision.

Extension

An analogy can be made between reactants in a reaction system and friends meeting at a football game. Present these situations to your students to help them relate kinetics to everyday events.

Situation	Relation to Kinetics
Imagine you attend two football games in one evening. The first game is a dud—hardly anyone is there. The second game is exciting and is packed with people. At which game are you more likely to run into someone you've been wanting to talk to?	Higher concentration or pressure leads to increased number of collisions.
Imagine you are meeting friends at the football game. Is it more likely for two of you happen to arrive at the same time or for all three of you to arrive at exactly the same time?	Two-body collisions are more likely to occur than three-body collisions.
Imagine you want to share some news with two friends. Will it be faster to wait until all three of you are together to share the news, or do you find one friend and share the news, then find the second friend and share the news?	Because three-body collisions are less likely to occur than two-body collisions, three or more reactants most likely combine in steps, or a reaction mechanism, that consist of smaller reactions between only two particles.
Imagine you are at a football game and want to ask another student to the upcoming school dance. But, the "right situation" never seems to arrive. Somehow the two of you are always surrounded by other people, with never a moment in exactly the right situation to ask that person to the dance. You did talk to the person at the game, but you go home without asking the person to the dance.	Collision geometry must be right for a successful collision to occur. If the geometry is not right, a collision may occur, but it will not necessarily go on to produce products.

Reference

Bilash, B.; Gross, G.; Koob, J. *A Demo A Day™ Volume 2—Another Year of Chemical Demonstrations*; Flinn Scientific, Inc.: Batavia, IL, 1998; Vol. 2, pp 154–155.

Materials for *Successful Collisions* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP2279	Balls, Styrofoam®, 19
AP2278	Balls, Styrofoam®, 39

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.