

Teacher Guide: Diffusion



Learning Objectives

Students will...

- Understand the meaning of diffusion and dynamic equilibrium.
- Describe how particles move in a gas.
- Understand that temperature is a measure of the average kinetic energy in a collection of particles.
- Conduct controlled experiments to explore how the rate of diffusion is affected by temperature, the size of the barrier, the size of the particles, and the number of particles.



Vocabulary

absolute zero, controlled experiment, diffusion, dynamic equilibrium, Kelvin scale, kinetic energy



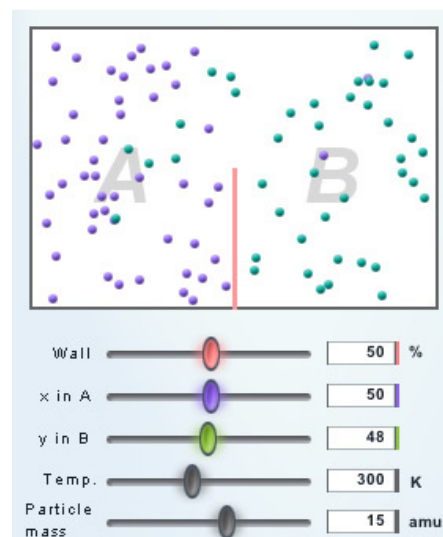
Lesson Overview

A fluid consists of a collection of particles that are in constant motion. Because of this motion, when another substance is added to the fluid, it will tend to spread from areas of high concentration to areas of low concentration. This process is called *diffusion*.

The *Diffusion Gizmo*TM allows students to see diffusion occurring at a molecular level. The Gizmo shows a chamber that is divided by a partial barrier. Over time, particles will migrate from one side of the chamber to the other. The barrier height, chamber temperature, number of particles, and particle mass all can be adjusted by the student.

The Student Exploration sheet contains two activities:

- Activity A – Students explore the effect of temperature on the rate of diffusion.
- Activity B – Students set up a controlled experiment to investigate the effect of a chosen variable on the rate of diffusion.



Suggested Lesson Sequence

1. Pre-Gizmo activity (🕒 5 – 10 minutes)

Stand in one corner of the room, and spray air freshener into the air. Ask students to raise their hands as soon as they smell the scent. As they raise their hands, the progress of the spray particles through the room can be traced. Ask your students why the air freshener spreads through the room. Does the air freshener fill the whole room, or does it stay in just one part?

Next, demonstrate diffusion by adding a drop of food coloring to a glass of water. After 5 minutes or so, the color will be evenly spread throughout the water.

2. **Prior to using the Gizmo** (🕒 10 – 15 minutes)
Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.
3. **Gizmo activities** (🕒 15 – 20 minutes per activity)
Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.
4. **Discussion questions** (🕒 15 – 30 minutes)
As students are working or just after they are done, discuss the following questions:
- What is the relationship between temperature and the speed of the particles?
 - Are all the particles in the chamber moving at the same speed?
 - How will each of the following changes affect the rate of diffusion? Why?
 - Increasing the size of the opening between the two sides of the chamber
 - Increasing the number of y particles in region B
 - Increasing the temperature
 - Increasing the size of the particles
5. **Follow-up activity: Semipermeable membranes** (🕒 1 hour)
Diffusion is often studied in relation to *semipermeable membranes* such as cell membranes. A semipermeable membrane allows some substances through, but not others. Use the following demonstration to show how some substances can diffuse through a semipermeable membrane but others cannot.
- Mix a few spoonfuls of cornstarch into a liter of water. Pour the starch solution into a sealable sandwich bag. Place the bag into a large beaker or a Mason jar.
 - Fill the Mason jar with an iodine solution. After one hour, the bag with the starch solution will have a purple color, indicating that the iodine diffused through the bag and mixed with the starch solution inside the bag. There will be no color change outside of the bag, indicating that the starch did not diffuse through the bag. The plastic is permeable to iodine but impermeable to starch.

See the **Selected Web Resources** on the next page for detailed instructions.



Scientific Background

In any fluid (gas or liquid), particles are in constant random motion. Individual molecules move until they hit another molecule, rebound, and continue to crash into other molecules in an endless dance. The temperature of a fluid is a measure of the average kinetic energy of the molecules. Kinetic energy is proportional to mass and to the square of velocity ($KE = mv^2 / 2$). Therefore, doubling the mass of the molecules also doubles the kinetic energy (and thus the temperature) of the fluid. Doubling the average velocity of the molecules will cause the kinetic energy (and the temperature) to quadruple.

Physicists use the *Kelvin scale* to measure temperature. Each unit of the Kelvin scale is equivalent to one degree Celsius, but the zero point of the Kelvin scale is *absolute zero*, the coldest possible temperature. At absolute zero, or $-273.15\text{ }^{\circ}\text{C}$, there is no molecular motion at all. The Kelvin scale is handy to use when studying molecular motion because doubling the Kelvin temperature is equivalent to doubling the kinetic energy of the fluid. This is not true when temperature is measured on the Celsius or Fahrenheit scales.

The random motion of molecules in a fluid leads to diffusion, or the net movement of molecules from areas of high concentration to areas of lower concentration. This process is modeled in the *Diffusion Gizmo*. **Figure 1** shows a high concentration of molecules in region A and no molecules in region B. A solid barrier separates the two areas.

When the barrier is opened (**Figure 2**), random motions carry some molecules from region A to region B. Because there are many more molecules in region A than B, most of the motion is to the right (large arrow). Only a few molecules move from region B to region A (small arrow). As the concentration of molecules in region B increases, however, the number of molecules moving from region B to region A also increases. When there are equal numbers of molecules in each region (**Figure 3**), the number of molecules moving past the barrier in each direction is also equal. At this point, *dynamic equilibrium* has been reached and particle concentrations won't change very much.

The rate of diffusion across the barrier will depend on many factors. The larger the opening is between the two regions, the greater the rate of diffusion. Heating the fluid will increase the speed of molecules and thus increase diffusion rates. (Note: The change in molecular speed is not directly proportional to the increase in temperature. In fact, heating air from $0\text{ }^{\circ}\text{C}$ to $100\text{ }^{\circ}\text{C}$ only increases the average molecular speed by 17%.)

Increasing the size of molecules will slow down diffusion because, at equal temperatures, larger molecules are moving more slowly than smaller molecules. (Recall that temperature measures the average kinetic energy of molecules, which is proportional to mass and velocity squared.) Increasing the number of molecules also will slow down diffusion because collisions between molecules will increase. This decreases the distance that a molecule travels before changing direction and slows the spread of molecules from one place to another. (Imagine trying to reach the other side of a crowded room as opposed to a nearly empty room.)



Selected Web Resources

Diffusion experiment: http://www.science-class.net/Lessons/Osmosis/diffusion_baggie.pdf

Diffusion of ammonia and HCl: http://www.practicalphysics.org/go/Experiment_170.html

Diffusion tutorial: http://www.mun.ca/biology/Osmosis_Diffusion/tutor2.html

Diffusion and osmosis: <http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/diffus.html>

Related Gizmos:

Osmosis: <http://www.explorellearning.com/gizmo/id?418>

Temperature and Particle Motion: <http://www.explorellearning.com/gizmo/id?555>