

Teacher Guide: Temperature and Particle Motion



Learning Objectives

Students will...

- Understand that a gas consists of particles called molecules, all moving and colliding with each other.
- Observe that the molecules in a gas are not all moving at the same speed.
 - See the molecular speeds on the Maxwell-Boltzmann distribution.
- Know that temperature is a measure of the average kinetic energy of gas particles:
 - As temperature rises, the average particle velocity increases.
 - At a given temperature, more massive particles will move more slowly than less massive particles.
- Calculate three different measures of the average velocity of particles in a gas.



Vocabulary

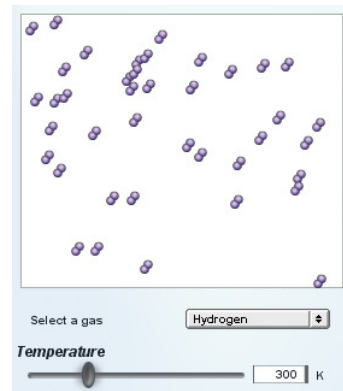
absolute zero, Kelvin scale, kinetic energy, Maxwell-Boltzmann distribution, molar mass, molecule, temperature, universal gas constant



Lesson Overview

Temperature is a measure of the *average* motion of particles. Because particles in a gas move at a variety of speeds, the velocity distribution is shown by the Maxwell-Boltzmann curve.

The *Temperature and Particle Motion Gizmo™* demonstrates the relationship between the temperature of a gas and the motion of its particles. A sample of moving particles is shown on the left side of the Gizmo, and the corresponding Maxwell-Boltzmann distribution is shown on the right. Students can change the temperature and the gas that is shown.



The Student Exploration sheet contains two activities:

- Activity A – Students explore the relationships between temperature, particle velocity, and particle mass.
- Activity B – Students interpret the Maxwell-Boltzmann distribution and calculate three versions of the average molecular velocity.



Suggested Lesson Sequence

1. **Pre-Gizmo activity: Plop, plop, fizz fizz** (🕒 5 – 10 minutes)
 Divide your students into groups. Give each group a beaker of hot water, a beaker of very cold water, and two Alka-Seltzer™ tablets (or equivalents). Have students drop a tablet into each beaker, and record their observations. Students will observe that the tablets dissolve much more quickly in hot water than in cold water.

After the experiment, ask students why the tablets dissolved so much more quickly in hot water. At the molecular level, what was happening in each beaker?

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:

- Do all of the molecules in a gas move at the same velocity?
- How does the temperature of a gas relate to the average velocity of its molecules?
- What would you see if the temperature was absolute zero? [Note: absolute zero is not shown in the Gizmo because at low temperatures gases change phase to liquids and/or solids. Helium has the lowest boiling point, 4 K.]
- Why do heavier gases move more slowly than lighter gases at the same temperature? [Temperature is a measure of average kinetic energy. If the same amount of energy is added to lighter and heavier molecules, the lighter molecules will move more quickly.]
- What does the Maxwell-Boltzmann distribution indicate about molecular velocities?
- Why is the mean particle velocity always greater than the most probable particle velocity?

5. **Follow-up activity: Explain everything** (🕒 variable)

The fact that higher temperatures correspond to faster particle velocities has myriad implications in science. Ask students how what they have learned explains each of the following phenomena:

- Phase changes
- An Alka-Seltzer tablet dissolving more quickly in hot water than in cold water
- A hot-air balloon rising in the sky
- Convection
- How a car engine works (hint: what happens inside a piston?)
- Why sugar dissolves more easily in hot water than cold water

Many of these phenomena can be explored with Gizmos. See the **Selected Web Resources** on page 3 of this document for Gizmos on phase changes, chemical reactions, convection, and solubility.



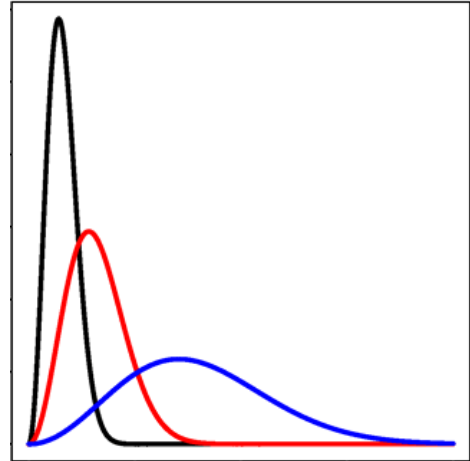
Scientific Background

The temperature of a gas is a measure of the average kinetic energy of its molecules. The kinetic energy of an object is given by the following formula:

$$KE = mv^2 / 2$$

Temperature increases when the velocity or mass of molecules is increased. For example, doubling the average velocity of molecules causes the temperature to quadruple. If two gases at equal pressure and temperature are compared, the molecules in the lighter gas are moving more quickly than the heavier molecules.

In any gas, molecules will move at a variety of velocities. The relative proportions of molecules moving at different velocities is given by the Maxwell-Boltzmann distribution. Because the minimum velocity value is 0, the distribution is asymmetrical with a longer tail on the right than on the left. This fact explains why the mean velocity (\bar{v}) is always greater than the mode velocity, or most probable velocity (v_p). The diagram at right shows velocity curves for a cold gas (black), a warm gas (red), and a hot gas (blue). Notice that the distribution becomes flatter and wider as temperature increases. At higher temperatures there is a wider distribution of particle velocities than at low temperatures. Even at extremely high temperatures there will still be a few slow-moving molecules.



When gas particles in a container are heated, they move more quickly and collide more forcefully with the walls of the container. This increases the pressure on the walls of the container. If the container can be expanded (like a balloon), the volume of the container will increase and the density of the gas will decrease. The relationships among the temperature, pressure, and density of a gas are approximated by the *ideal gas law*: $pV = nRT$, where p is pressure, V is volume, n is the amount of gas, R is the universal gas constant, and T is the temperature.



Selected Web Resources

Temperature: <http://hyperphysics.phy-astr.gsu.edu/HBASE/thermo/temper.html>,
<http://hyperphysics.phy-astr.gsu.edu/HBASE/thermo/temper2.html#c1>

Physics of temperature: <http://eo.ucar.edu/skymath/tmp2.html>

Maxwell-Boltzmann distribution: <http://neon.chem.uidaho.edu/~honors/111%20Notes/boltz.html>

Kinetic theory (basic): <http://www.grc.nasa.gov/WWW/K-12/airplane/kinth.html>

Kinetic theory of gases: http://galileo.phys.virginia.edu/classes/252/kinetic_theory.html

Kinetic theory applet: http://comp.uark.edu/~jgeabana/mol_dyn/

Related Gizmos:

Phase Changes: <http://www.explorellearning.com/gizmo/id?557>

Collision Theory: <http://www.explorellearning.com/gizmo/id?553>

Conduction and Convection: <http://www.explorellearning.com/gizmo/id?658>

Boyle's Law and Charles' Law: <http://www.explorellearning.com/gizmo/id?422>

Diffusion: <http://www.explorellearning.com/gizmo/id?417>

Solubility and Temperature: <http://www.explorellearning.com/gizmo/id?384>