

Bridging the Gap I

"Hot Molecules": Kinetic Molecular Theory

The kinetic molecular theory is sometimes difficult to visualize. This activity is aimed at showing how temperature influences the motion and therefore the kinetic energy of molecules. According to the kinetic theory of matter, the molecules of a substance are in constant motion. The molecules move faster at high temperatures and slower at low temperatures. This can be clearly seen by looking at the rates of diffusion of food coloring dye molecules in common tap water. The average kinetic energy of a molecule is given by the equation

$$\overline{KE} = \frac{1}{2}m\overline{v}^2 = \frac{3}{2}RT$$

Here the average kinetic energy is \overline{KE} , the molar mass is m , the average velocity for the molecules is \overline{v}^2 , the universal gas constant is R , the absolute temperature is T . Remember the absolute temperature equals the Celsius temperature plus 273.15. This equation predicts that the average kinetic energy will increase with temperature. The physical result of higher velocities is a shorter time between molecular collisions. These collisions are important in diffusion and dispersion. Each collision will knock a molecule around a little bit. If a clump of dye molecules is buffeted by surrounding solvent molecules, each collision will act to break up the clump. Eventually the clump will be dispersed and the mixture will be uniform with a homogeneous color.

Equipment and materials

Microwave oven or source of hot water, ice cubes or source of ice cold water, three identical clear colorless 12 ounce glasses, plastic tumblers or jelly jars, three sheets of white paper, tap water and a package of Schilling® or other brand of food coloring.

1. Fill one of the glasses with approximately 8 ounces of room temperature water.
2. Fill the second glass with an equal amount of ice cold water.
3. Heat some water in either a microwave oven or on a stove top burner. Fill the third glass with an equal amount of hot water.
4. Place each of the glasses in front of a sheet of white paper so the paper acts as a white background.
5. Stir each glass of water and then allow the three glasses to stand for about 10 minutes so the water is as still as possible and there is no mechanical movement.
6. Select one of the food coloring dyes.
7. Carefully add one drop of dye to each of the glasses, starting with the coldest and ending with the hottest. Observe how the drop of dye spreads throughout the water.
8. Note the approximate time required for the food coloring to be uniformly dispersed in any one of the glasses.

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Observations

What food coloring did you use?

Did the food coloring disperse at the same rate in the three different-temperature water samples? Which of the water samples dispersed the food coloring the fastest?

How did the drop of dye behave in the glass of room temperature water?

How did the drop of dye behave in the glass of hot water?

How did the drop of dye behave in the glass of ice cold water?

Analysis

What do you think causes the dye molecules in the food coloring to disperse the way they did in the three samples?

Do you believe you would observe the same results if you changed the food coloring? Justify your answer.

Do you believe you would see the same results if you used a different solvent like rubbing alcohol? Justify your answer.

Relation to Kinetic Molecular Theory

How do your observations relate to the Kinetic Molecular Theory?