Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Student Exploration:** **Diffusion**

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

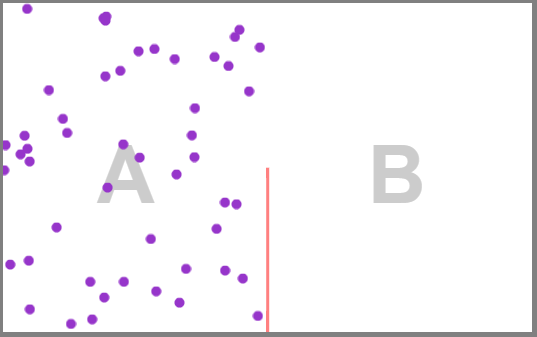
**Prior Knowledge Question** (Do this BEFORE using the Gizmo.)

Have you ever smelled microwave popcorn? The oddly enticing scent can fill a whole house.

How do you think the smell of popcorn spreads through the air? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**Gizmo Warm-up**

Smells are carried by tiny particles that move through the air. The *Diffusion* Gizmo shows gas particles in a chamber that is divided into two regions by a partial wall. Click **Play** (1) and observe.

1. Describe the motion of the gas particles. \_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Over time, what is happening? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

This process, in which particles move from an area of high concentration (region **A**) to an area of low concentration (region **B**), is called **diffusion**.

1. Select the BAR CHART tab, and observe the chart for a few minutes. After the first 30 seconds or so, how much do the numbers of particles in each region change?

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When the numbers don’t change much, the particles are said to be in **dynamic equilibrium**.

1. Click **Pause** (2), and select the GRAPH tab. What does the graph tell you about the number of particles in region A? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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| **Activity A:**  **Temperature and diffusion** | Get the Gizmo ready:   * Click **Reset** (3). * Set the **Wall** to 100%. | 417SE2 |

**Introduction:** In this Gizmo, temperature is measured on the **Kelvin scale**. On this scale, 0 K represents **absolute zero**, the coldest possible temperature. Water freezes at 273.15 K (0 °C), and water boils at 373.15 K (100 °C).

**Question: How does temperature affect the rate of diffusion?**

1. Observe: Set the temperature (**Temp.**) to 100 K, and press **Play**. Observe the motion of particles. Click **Reset**. Then set the temperature to 600 K, click **Play**, and observe.

How does the temperature of the gas relate to the motion of the particles? \_\_\_\_\_\_\_\_\_\_\_\_\_\_

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The temperature of a gas is a measure of the average **kinetic energy** of a set of particles. Kinetic energy (KE) depends on the velocity and mass of the particles (KE = *mv2* / 2).

1. Form hypothesis: How do you think temperature will affect the rate of diffusion? \_\_\_\_\_\_\_\_\_\_

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1. Experiment: Click **Reset**. Set the **Wall** to 50%, **x in A** to 100, **y in B** to 0, **Temp.** to 100 K, and **Particle mass** to 15 amu (atomic mass units). Select the TABLE tab. Press **Play**.

Click **Pause** when **x in A** first reaches 55% or below. Record this **Time to reach equilibrium** in the left table below.

Repeat four more times at 100 K, and then run five trials with the temperature set to 600 K.

**Temp = 100 K experiment**

|  |  |
| --- | --- |
| **Trial** | **Time to reach equilibrium** |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |

**Temp = 600 K experiment**

|  |  |
| --- | --- |
| **Trial** | **Time to reach equilibrium** |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |

**(Activity A continued on next page)**

**Activity A (continued from previous page)**

1. Calculate: Find the average time to reach equilibrium for each experiment:
   * 1. Average time to reach equilibrium at 100 K: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
     2. Average time to reach equilibrium at 600 K: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Draw conclusions: Compare the average times to reach equilibrium for each temperature.
   * 1. How did temperature affect the rate of diffusion? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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* + 1. Why do you think this was the case? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. Extend your thinking: Why do you think the experimental results were different for each trial?

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1. On your own: In our lives, we rarely experience temperatures that are above 373 K (100 °C) or below 273 K (0 °C). Investigate how much diffusion rates differ between these two temperatures. Describe the results of your experiments below.

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| **Activity B:**  **Rates of diffusion** | Get the Gizmo ready:   * Click **Reset**. | 417SE3 |

**Introduction:** The *Diffusion* Gizmo allows you to manipulate five variables: the **Wall**, the number of **x** particles in region **A**, the number of **y** particles in region **B**, the temperature, and the **Particle mass**.

**Question: How do factors other than temperature affect the rate of diffusion?**

1. Choose a variable: Pick a variable to investigate. Which one did you choose? \_\_\_\_\_\_\_\_\_\_\_
2. Form hypothesis: How do you think this variable will affect rates of diffusion? \_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. Set up experiment: In a **controlled experiment**, only one variable is manipulated, or changed. Set up your experiment so that there is just one difference between set-up A and set-up B. List the Gizmo settings you will use for each set-up below.

**Set-up A**

**Wall** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**x in A** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**y in B** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Temp.** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Particle mass** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Set-up B**

**Wall** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**x in A** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**y in B** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Temp.** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Particle mass** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Gather data: Use the Gizmo to fill in each table. As before, the “time to reach equilibrium” is the time it takes for the number of **x** particles in region A to reach 55% or lower.

**Set-up A**

|  |  |
| --- | --- |
| **Trial** | **Time to reach equilibrium** |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |

**Set-up B**

|  |  |
| --- | --- |
| **Trial** | **Time to reach equilibrium** |
| 1 |  |
| 2 |  |
| 3 |  |
| 4 |  |
| 5 |  |

**(Activity B continued on next page)**

**Activity B (continued from previous page)**

1. Calculate: Find the average time to reach equilibrium for each experiment:
   * 1. Average time to reach equilibrium for set-up A: \_\_\_\_\_\_\_\_\_\_\_\_
     2. Average time to reach equilibrium for set-up B: \_\_\_\_\_\_\_\_\_\_\_\_
2. Draw conclusions: Compare the average times to reach equilibrium for each set-up.
3. How did the variable you investigated affect the rate of diffusion? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. Why do you think this was the case? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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1. On your own: Investigate the remaining variables. Record all experimental results in your notes. Summarize your findings in the space below.

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