

## Ideal Screen

Pump gas molecules into a container and discover what happens as you change the volume, add or remove heat, and more.

**COUNT** the number of particle-wall collisions

**RESIZE** the container without doing work

**ADD** or **REMOVE** heat

**HOLD** a parameter constant

**VIEW** container width

**PUMP** particles into the container

**EMPTY** the container

Gas Properties

## Explore Screen

Discover what happens when a gas is compressed or expanded, and identify when P-V work is done on or by a gas.

**OPEN** the lid

**COMPRESS** or **EXPAND** the volume to explore P-V work.

**PAUSE** and **STEP** forward frame-by-frame

**TOGGLE** units

**ADD** or **REMOVE** particles 50 at a time or 1-by-1

Gas Properties

## Energy Screen

Examine speed and kinetic energy distributions, and compare heavy and light gases.

The Energy Screen interface features a central simulation window showing a mixture of blue and orange particles. To the left, there are three data panels: 'Average Speed' showing 463 m/s for blue and 1260 m/s for orange; 'Speed' showing a histogram of particle speeds; and 'Kinetic Energy' showing a histogram of particle kinetic energies. To the right, there are control panels for 'Particles' (with 'Collisions' checked and 'Heavy' and 'Light' species selected) and 'Injection Temperature' (set to 300 K). A pressure gauge shows 86.7 atm. At the bottom, there are navigation icons for 'Ideal', 'Explore', 'Energy', and 'Diffusion', along with the PhET logo.

**OBSERVE** the average speed of each species

**EXAMINE** speed and energy distributions in real time

**SEE** distributions of each species

**EXPLORE** systems with or without particle-particle collisions

**PUMP** particles in at varying temperatures

## Diffusion Screen

Explore how two gases mix, and experiment with the factors that affect the rate of diffusion.

The Diffusion Screen interface shows a central simulation window with a vertical divider separating two chambers of particles. A 'Data' panel above the window displays particle counts and average temperatures: 89 blue particles at 320 K and 11 orange particles at 280 K. To the right, a control panel allows for setting 'Number of Particles' (100 and 200), 'Mass (AMU)' (28 and 4), 'Radius (pm)' (150 and 75), and 'Initial Temperature (K)' (300 and 300). It also includes a 'Reset Divider' button and checkboxes for 'Center of Mass', 'Particle Flow Rate', 'Scale', and 'Stopwatch'. A 'Particle Flow Rate' indicator shows a double-headed arrow between the chambers. At the bottom, there are navigation icons for 'Ideal', 'Explore', 'Energy', and 'Diffusion', along with the PhET logo.

**TRACK** the number of particles and temperature on each side

**EXPERIMENT** with number, mass, radius, and initial temperature

**VISUALIZE** the flow of particles between sides

**MEASURE** diffusion rate

## Customization Options

The following query parameters allow for customization of the simulation, and can be added by appending a '?' to the sim URL, and separating each query parameter with a '&'.

- `colorProfile=projector` - changes the simulation colors for better contrast when projecting, also found in the PhET menu under Options > Projector Mode.
- `pressureNoise=false` - removes the noise displayed in the pressure gauge, also found in the PhET menu under Options > Pressure Noise.
- `screens=1,3` - launches the screens listed after the '=' (screens 1 and 3 in this example). Each screen should be separated by a comma. For more information, visit the [Help Center](#).

## Model Simplifications

- The particle-particle collisions are modeled as hard sphere collisions. A detailed description of the model can be found [here](#).
- The container depth (4 nm) and height (8.75 nm) are constant, so volume varies linearly with width.
- The light particles have a mass of 4 AMU and the heavy particles have a mass of 28 AMU. While these masses respectively correspond to He and N<sub>2</sub>, the radii differ to optimize the visual size difference.
- The pressure in the model is derived from the ideal gas law. The pressure will be non-zero as soon as  $N > 0$ , and remains constant until  $N$ ,  $T$ , or  $V$  is changed. The pressure displayed on the pressure gauge may vary from the model value under certain circumstances.
  - The pressure gauge will display zero pressure until the first particle-wall collision.
  - If the Pressure Noise option is on, the pressure reading will fluctuate every 0.75 ps by a maximum of 50 kPa. The amount of pressure noise is inversely proportional to the pressure, and for  $T \leq 50\text{K}$  it will linearly decrease until it becomes 0 kPa when  $T \leq 5\text{K}$ .
- Moving the container wall on the Ideal screen will not do any work on/by the system. When the container wall is grabbed, the simulation will pause. Upon release, the particles will instantaneously redistribute in the container, and their speeds will remain unchanged.
- On the Explore screen, moving the container wall will affect the velocity of the particles colliding with it. The wall has speed limit of 800 pm/ps when reducing the volume to avoid always blowing the lid.
- Adding particles to the container will not change the temperature of the system, as the newly-added particles are given the appropriate velocity to match the temperature of the gas in the container. On the Energy Screen, use the Injection Temperature controls to instead set the temperature of the particles before adding them to the container.
- When the system temperature is below 0.5 K, the display will show 0 K. Particle motion will eventually stop if the container is cooled further, though this may take some time.
- The Energy and Kinetic Energy histograms are designed to be qualitative. The y-axes autoscale, with horizontal lines representing 50 particles. The x-axes are static, and in rare cases some data may fall off-scale. The data refreshes every 1 ps.
- The Particle Flow Rate arrows are proportional to the number of particles that have crossed the midline and is time-averaged over 300 ps.

## Suggestions for Use

### Sample Challenge Prompts

- Describe the relationship between particle-wall collisions and pressure.
- Design an experiment to determine the relationship between two gas properties, such as  $P$  and  $T$ .
- Identify the relationship between pressure, volume, temperature, and number of gas molecules.
- Compare and contrast the effect of moving the container wall on the temperature of the system on the Ideal and Explore screens. What effect does the speed of the wall have on the temperature change?
- Describe the shape of the speed distribution. Which species is faster, on average? What happens when particle-particle collisions are turned off?
- Explain how two gases mix.
- Describe what the Particle Flow Rate arrows represent.
- Design an experiment to determine the factors which affect the rate of diffusion.

See all published activities for Gas Properties [here](#).

For more tips on using PhET sims with your students, see [Tips for Using PhET](#).