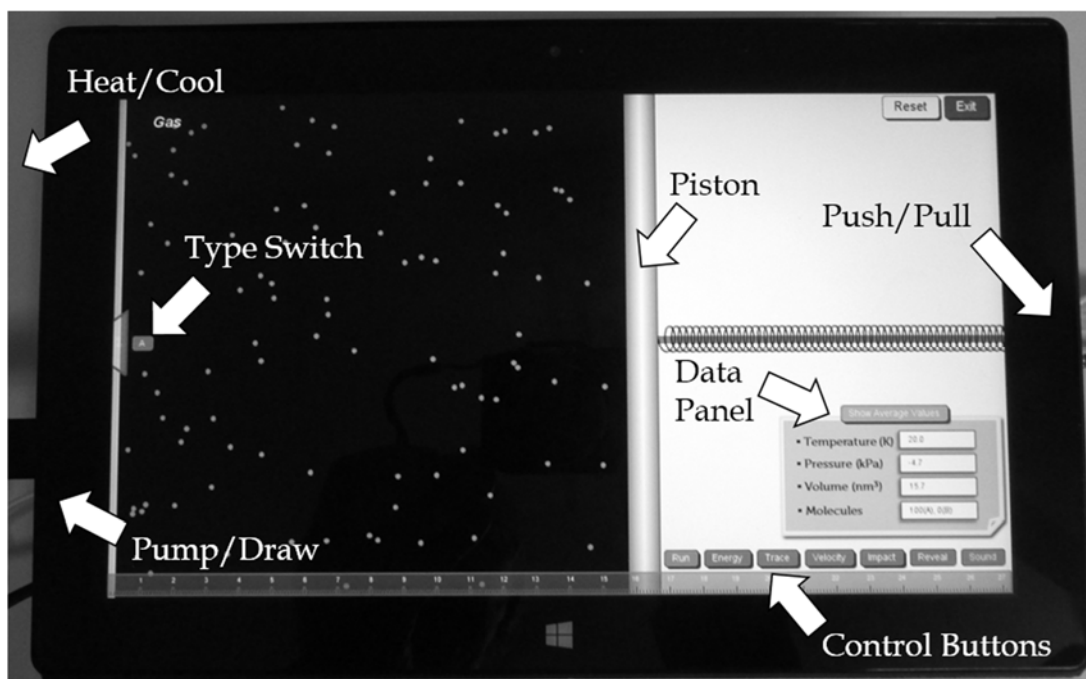


# Mixed-Reality Gas Lab Instructions

The “Frame” can be thought of as an atomic microscope. You can observe and manipulate simulations of tiny gas molecules that you wouldn’t be able to see and interact with otherwise.



An illustration of the Gas Frame

## What you can do

- **Start the Frame.** Double-click “gas-frame.bat” on the USB drive. The screen will show gas molecules in a container with a piston. The molecules are initially invisible but can be shown by clicking the Reveal button.
- **Run the Frame.** Click the **Run** button to start the simulation. To pause the simulation, click the **Run** button again. To start over, click the **Reset** button.
- **View energy of molecules.** Hold down the **Energy** button to show colors that represent the kinetic energy of individual molecules: red for high energy and white for low energy.
- **View trace of a molecule.** Hold down the **Trace** button to highlight a randomly selected molecule and its traveling path.
- **View velocities of molecules.** Hold down the **Velocity** button to show arrows that represent the velocities of the molecules. Longer arrows stand for greater speeds.
- **View impulses of molecules on the piston.** An impulse measures the impact of a molecule on the piston when it collides with the piston. Hold down the

**Impact** button to show the impulses. Longer arrows represent greater impulses. Impulses of different types of molecule are shown in different colors.

- **Change molecule types.** Click the small rectangle marked with “A” or “B” near the nozzle on the left edge of the screen for the new molecules added from the nozzle to switch to type B or A molecule. The mass of a type B molecule is four times of that of type A molecule. Initially, there are 100 type A molecules in the container.
- **Change the number of molecules.** Pump in or take out molecules by pushing or pulling the plunger attached to the left edge of the Frame. The maximum number of molecules that you can add is 200.
- **Compress or decompress the gas.** Increase or decrease the external pressure by pushing or pulling the spring attached to the right edge of the Frame. To maintain a constant pressure, fix the spring at various positions by pushing the metal pin through different holes. *When you reset the Frame, make sure to pull out the metal pin and let the model start with the spring free. This will give you consistent starting values.*
- **Change temperature.** Use objects at different temperatures to touch the tip of the temperature sensor on the left edge of the Frame to heat or cool the molecules. You can set four different temperatures using 1) room temperature (default), 2) your fingers, 3) a jar of ice water, and 4) a jar of hot water. Make sure the jars are properly sealed to prevent water damages to the computer and electronic sensors.

## Experimental results

The instantaneous values of temperature, pressure, volume, and number of molecules are shown in the data panel at the lower-right part of the screen.

- **Temperature** of the gas is measured in Kelvin (note that the temperature is exaggerated in order to create dramatic differences in molecular motion).
- **Pressure** of the gas is measured in an arbitrary unit.
- **Volume** of the gas is represented by the location of the piston on the ruler.
- **Molecules** are the number of molecules of different types in the container.

**Important: Every time you change a condition, you must give the system at least five seconds to reach equilibrium. Notice that, even at equilibrium, the readings can fluctuate quite a bit. Hold down the “Show Average Values” button for 5-10 seconds to obtain more stable readings.**