

## States Screen

Heat or cool atoms and molecules and watch as they change between solid, liquid and gas phases.

**VIEW** the temperature in K or °C

**OBSERVE** the motion of the sample

**CHOOSE** an atom or molecule

**EXPLORE** solid, liquid, or gas

**ADD** or **REMOVE** heat from the system

States of Matter: Basics

## Phase Changes Screen

Explore how the system behaves as the atoms and molecules are heated, cooled, compressed, or more particles are added.

**COMPRESS** the sample

**PUMP** in additional atoms or molecules

**PAUSE** and step through the motion

**VIEW** a qualitative Lennard-Jones potential

**VIEW** a qualitative phase diagram

States of Matter: Basics

## Customization Options

- The simulation colors can be changed for better contrast when projecting by clicking on the PhET menu and selecting Options > Projector Mode. Alternatively, append `?colorProfile=projector` to the end of the simulation URL.

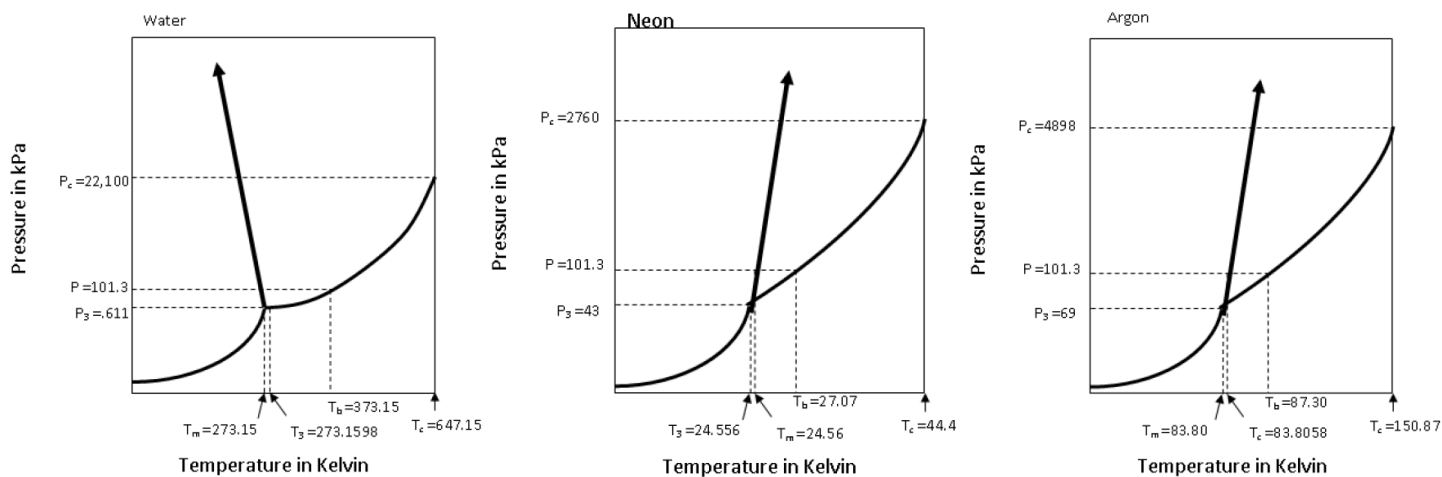
## Model Simplifications

- The model works best when there are at least (roughly) 15 particles in the container. It is possible to create situations where there are only a few particles in the container and, in these situations, students may observe some odd behaviors. One example is occasional visible changes to the velocity of individual particles. If students observe such things, they should be told that this is due to the limitations of the model, and doesn't represent "real world" phenomena.
- The number of particles that can be pumped into the system is limited. The indicator bars on the bicycle pump display how many additional particles can be pumped into the system.
- This simulation is intended for studying equilibrium states. As such, adding/removing heat, adjusting the volume, and pumping in additional particles is purposely kept slow so that the system can generally equilibrate as the changes are made. (Faster changes to the system, if allowed, would produce a greater variety of system states.)
- Latent heat is not addressed or supported by the model in this simulation.
- The temperature of the system is calculated from the velocities of the particles, and may change as more particles are pumped into the system.
- The pressure in the system is derived from the momentum transfers between the particles and the container walls. As a result, the pressure at 0 K will be zero.
- It is possible to reach absolute zero in the simulation, but the rate of temperature change slows down substantially as 0 K is approached. This is intentional, since it is very difficult to make a system of molecules this cold. True absolute zero is impossible to achieve, so this should be thought of as rounding down from anything below 0.5 K.
- For solid water, we wanted to show that there is space between the molecules. The correct structure of solid water requires a 3D view, but with minor compromises, we were able to show the situation qualitatively in 2D. Additionally, the solid water particles vibrate more than expected. A resource for the most common visual for ice structure can be found [here](#).
- Some amount of gravity is simulated, but it is minimal - just enough to keep the solid forms of the substances on the floor of the container. For this reason, substances in their liquid form don't always spread out along the bottom of the container, like water does in a glass. The liquid phase is still visually distinct from the other phases in terms of inter-molecular spacing and velocity.
- While plasma is a state of matter, we have deliberately chosen not to model it in this simulation.
- For younger students, it may be important to explain that the hand and the container are not at all to scale, since in the real world they too are made of atoms and molecules.

## Phase Diagrams

The sim is not designed to be used as a comprehensive tool for learning about phase diagrams, instead the focus is on phases of matter. The phase diagram axes do not have scales, but are meant to give students a general idea about understanding phase diagrams. The small number of particles shown and

the simplicity of the underlying models makes it difficult to map accurately the exact phase to the correct regions of the phase diagram. However, we felt there would be some benefit to students being exposed to a simplified phase diagram. (Phase diagrams for water, neon, and argon are illustrated below.) In the sim, the diagram marker remains on the coexistence line between liquid/gas or solid/gas (and is extrapolated into the critical region). If this approximation does not fit your specific learning goals, and you are concerned this might cause confusion, you can encourage your students to keep the phase diagram closed.



**Legend**       $T_m$  = melting point       $P_3$  = triple point       $P_c$  = critical point  
                   $T_b$  = boiling point       $T_3$  = triple point       $T_c$  = critical point

## Suggestions for Use

### Sample Challenge Prompts

- Draw a picture of each substance as a solid, liquid, and gas. Describe the differences and similarities between each state.
- Explore how you can change the state of matter of the substance in the container.
- Describe the difference in the movement of the particles in a solid, liquid, or gas.
- Predict what happens to the substance when it is heated or cooled.
- Describe a method to stop the atoms or molecules from moving.
- Explain why some molecules begin sticking together when you add in more molecules.

See all published activities for States of Matter: Basics [here](#).

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