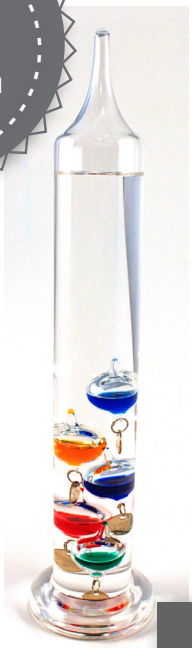
TEACHER'S GUIDE

GRADE LEVEL
ALL AGES
ADULT SUPERVISION REQUIRED



GALILEO THERMOMETER

ITEM# 1167-00

PROPERTIES OF MATTER - DENSITY

The Galileo thermometer consists of a sealed glass tube that is filled with water and several floating bubbles. The bubbles are glass spheres filled with a colored liquid. Attached to each bubble is a little metal tag that indicates the temperature (Fahrenheit) - a beautiful way to demonstrate pressure and fluid principles! Overall Height is about 13” (330mm).

Materials

- various liquids with different densities such as: light karo syrup, water, vegetable oil, dawn dish soap (blue), rubbing alcohol, lamp oil, honey
- ice
- graduated cylinder
- pan balance
- test tubes

Introduction

Matter is made of particles too small to be seen. Those particles can be atoms, ions, or molecules. Density is a ratio of the mass of the particles and the volume that they have (the space they occupy). These particles are attracted to each other by electrical forces – negative and positive which makes a large collection of them large enough to see – bulk matter.
The stronger the attraction of the particles for each other makes the matter denser – the mass of the particles takes up less space. This explains why mercury is denser than water – the atoms that make up mercury are more attracted to each other than the molecules in water are attracted to each other.

Matter that is a solid at room temperature has stronger attractive forces than matter that is a liquid at room temperature. Gasses have nearly negligible attractive forces for each other at room temperature. The particles that make up matter are always moving – in solids it is helpful to visualize this as vibrating particles. Temperature is average kinetic energy. The more the particles vibrate, the more kinetic energy they have. This increased energy is how a solid substance turns into a liquid and then turns into a gas.

The reverse change in state happens if the particles vibrate less. As energy increases the particles pull away from each other and overcome the attractive forces holding them together. As energy decreases the particles get closer and attractive forces are stronger. Density changes if the mass of the particles stays the same but the space they occupy changes.

The Galileo thermometer is a perfect tool to introduce the particulate nature of matter, the attractive forces holding matter together, and how energy changes affect those attractive forces. It allows students to practice these abstract atomic concepts by observing macroscopic changes in the spheres and inferring what that means must be happening at the atomic level.

History

It is thought that Galileo is responsible for describing how an object can show changes in thermal energy through the invention of the thermoscope. However, this is not certain.

How it works

An object immersed in a liquid is affected by two primary forces – gravity pulling it down and buoyancy pushing it up. The glass tube is filled with water and glass bulbs that may also be filled with water (and coloring) or possibly alcohol. A metal tag is attached to the bulbs that indicates the temperature. The bulbs have almost the same density as the water in the tube. They will sink as the density changes, the temperature of the water (and therefore the room) is the bulb at the bottom of the floating bulbs and above the bulbs that have sank. Water expands or contracts when the temperature (average kinetic energy) changes. It is important to not mislead students regarding water and other liquids. Water is actually less dense as a solid as compared to when it is a liquid because of hydrogen bonding. However, when it does not have a change in state and stays a liquid it actually gets denser as it gets colder. Cold water will sink in room temperature water.

GLOSSARY

- atoms
- buoyancy
- density
- gravity
- hydrogen bonding
- mass
- molecules
- particle diagrams
- volume

ACTIVITIES

1 Present Galileo's thermometer to them. Ask them how they think it works.

Why do the bulbs float?
When do they stop floating?
What are the two forces acting on each bulb?

Ask them to draw a particle diagram of the water in the tube and the particles inside one of the bulbs at the bottom. Do one for a bulb at the top and a bulb suspended in the middle of the tube.
Does the mass change in the bulb? (No)
So the volume must change (the spaces between the particles) .

2 Rank densities by experimentation with liquids: Provide students with small quantities of the liquids, droppers or pipettes and test tubes. Ask students to rank their relative densities.

A final assessment should include a diagram of how the liquids would layer in the same test tube.

3 Melt ice in graduated cylinder: Water is unique in that it is less dense as a solid than as a liquid. However, if there is no change in state, cold water is more dense than warm water.

Provide graduated cylinders and ice to your students. Have them measure 50mL of water into the cylinder and then add their ice.
Measure the total volume before the ice has melted.
Predict if the total volume will increase, decrease, or stay the same. Justify your prediction.
Measure it again after it has melted. The total volume will less after the ice has melted because the liquid particles take up less space than the solid particles.

Ask students to draw particle diagrams for the before and after. How would the particle diagrams be different the matter were not water – say iron? Solid iron is more dense than liquid iron.

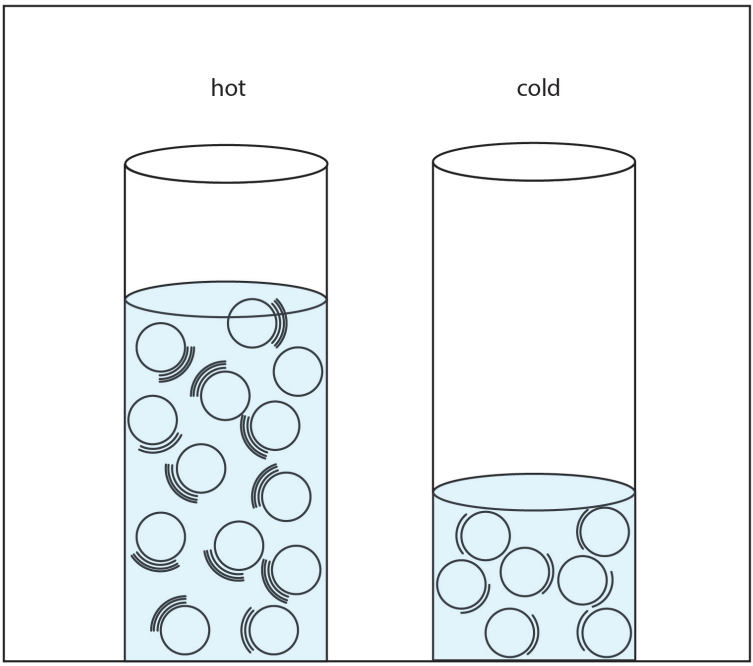
4 Calculate density of water versus baby oil using measurements: Provide two unknown samples of clear liquids to your students labeled A and B. (water and baby oil work nice and are safe).

Tell them to make the necessary measurements and calculate densities of the two liquids. Provide graduated cylinders and pan balances.

Note

It is always best to practice an experiment ahead of time to be able to best present it to the class.

ACTIVITIES



Once they have a density, provide them with the correct density and calculate percent error. They should list possible sources of error in their measurements and how that would affect the calculation.

5 Baby food jars, hot colored water and cold colored water: Put red hot water in a baby food jar. Put blue colored cold water in a baby food jar. Hot water is less dense than cold water. Ask students to predict what would happen if the hot water jar is inverted onto the cold water jar. Demonstrate it after they have predicted.

Use an index card over the hot water jar, turn it over and place it on the cold water jar. Carefully remove the index card. (the red hot water stays separate from the blue cold water) Ask students to predict what will happen if the cold water is on top. Demonstrate (the more dense blue cold water sinks into the red hot water quickly).

Discussion

Additional Discussion and Real Life Applications

1. How does a thermometer work?
   Have student explanations include thermal transfers (heat – by way of conduction or convection) and expansion/contraction of the alcohol.

   Why is alcohol used instead of mercury in classrooms today?
   Why isn't water used?

2. Students should draw particle diagrams of thermal transfer. They should include relative distances between particles (potential energy) and something
   to show vibration (kinetic energy) of the particle.

3. Is there a particle to show heat?
   Is heat matter?
   What is the difference between thermal energy, temperature, and heat?

4. Have students research how unequal heating causes atmospheric and oceanic circulation.

5. Ask students to draw and present particle diagrams for the densities of the liquids investigated in the activities.

Next Generation Science Standards

Students who demonstrate understanding can:

5-PS1-1. Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-3. Make observations and measurements to identify materials based on their properties.

MS-PS1-1. Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

MS-ESS2-6. Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

Standards Key

K = Kindergarten
3 = Third Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science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