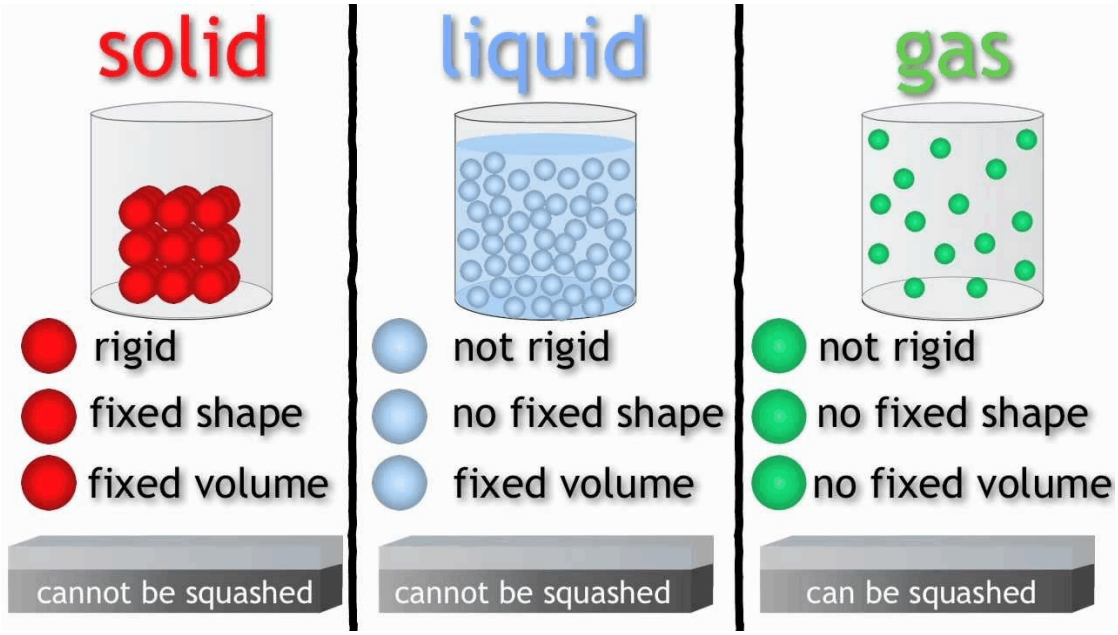
STATION 1

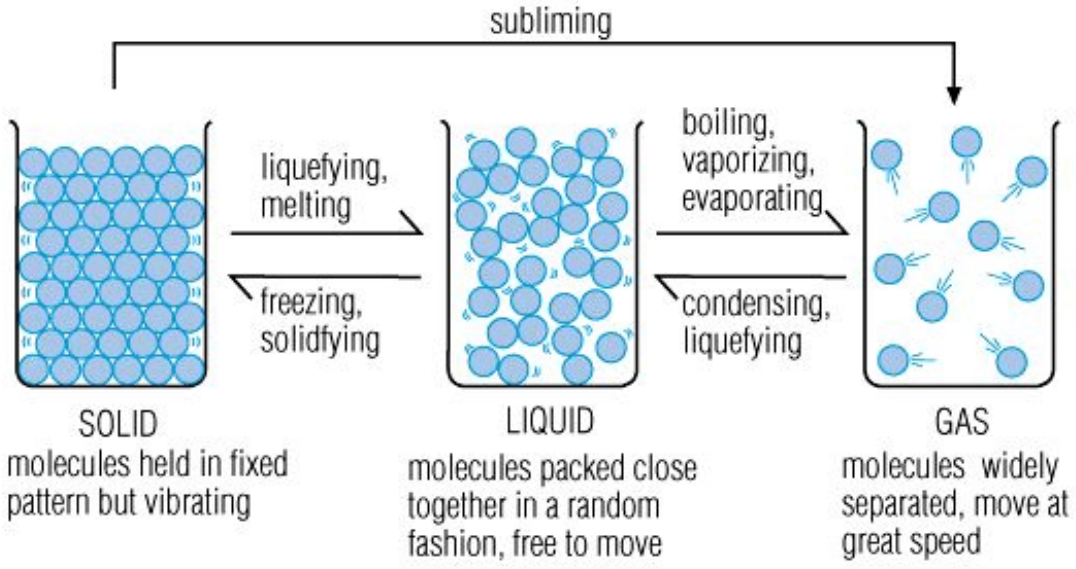
STATES OF MATTER, RELATIVE DENSITIES OF SOLIDS AND LIQUIDS:

1. Which test tube contains water?
2. Should a solid float or sink in its liquid? Explain your answer.
3. If the behavior of the solid-liquid density relationship of water were reversed, would life in lakes that freeze in the winter be affected?

4. Bonus question - How many water molecules are in the test tube and would that number of regularly sized marshmallows cover the earth?

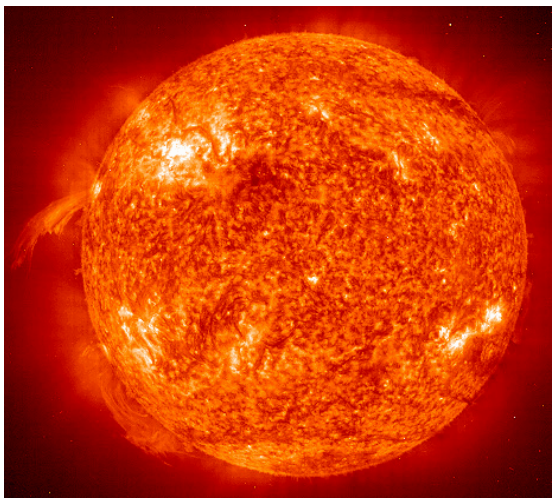
Concepts - States of Matter, Changes of State





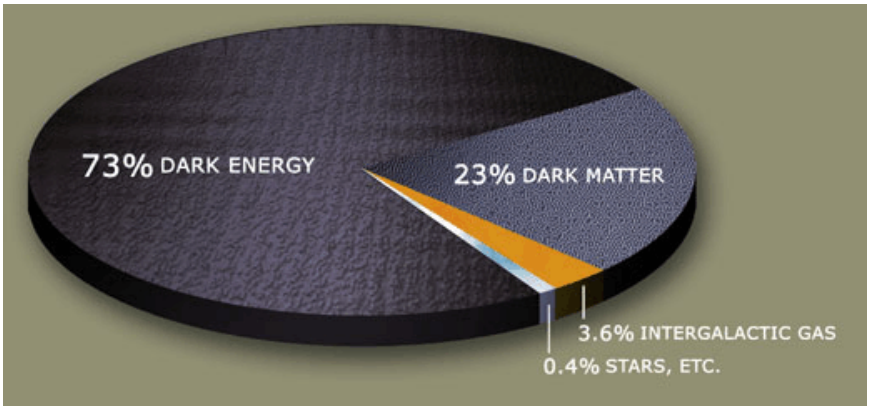
Increasing energy →

In the solid state, the atoms, molecules or ions are held in place by attractions. If the solid is heated, eventually, at the melting point there will be enough energy to overcome the attractions and the particles will be able to slide by each other . At this point, a state of matter or phase change occurs from solid to liquid. Substantially more heating overcomes the attractions that hold the particles next to each other. This results in boiling and a state of matter or phase change from the liquid to the gaseous state. Lowering the temperature of a gas reverses the process first with the gas condensing to a liquid and eventually with the liquid solidifying at the freezing point back to the original solid state.



It is commonly taught that there are 3 states of matter: solids, liquids and gases. However, since the sun and stars are a fourth state of matter called a plasma or ionic matter, most of the visible universe is not solid, liquid or gas.

Despite what appears to be a huge amount of matter, matter as we know it or atomic and ionic matter comprise only a few percent (about 4%) of the stuff in the Universe.

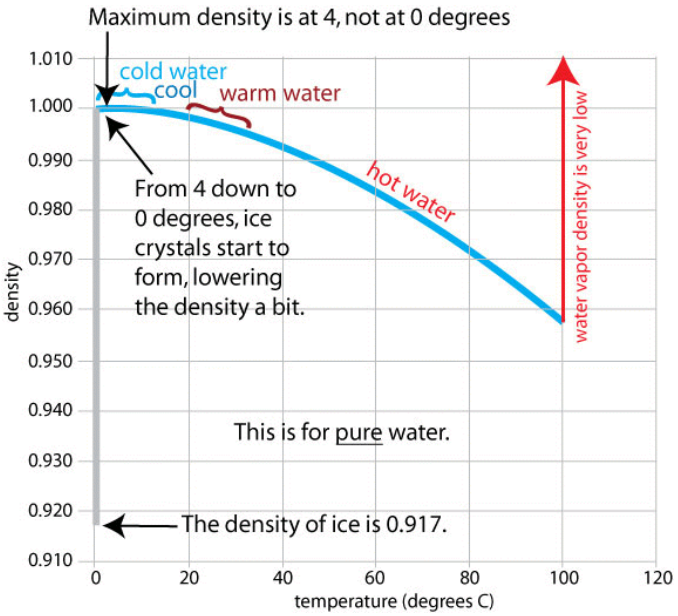


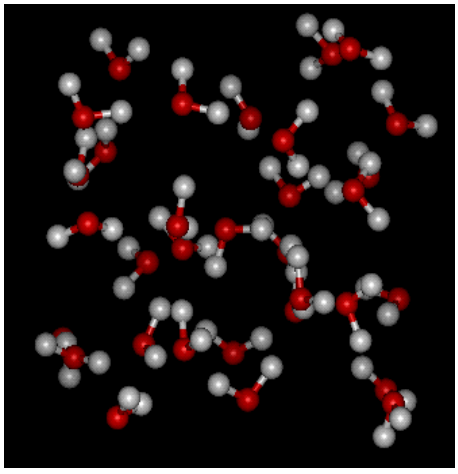
Dark matter and dark energy for the most part still remain a mystery to science and represent a very fertile area for research.

Each of the test tubes above contains one and only one substance but two phases of each substance are present in each tube. One of the substances exhibits considerably different behavior than the other five**. Which substance apparently exhibits anomalous behavior and is this behavior important to us**?

Millions of substances have been characterized (some properties determined) by chemists. Of the millions, it is interesting and astonishing to note that almost all of us have seen the liquid and solid phase of the same substance in the same container only for the substance, water. In other words the question of whether the solid sinks or floats in its own liquid is observed by most for water only. As a result, the behavior of water is accepted by most as the norm. However, think about this. As the liquid condenses, it should contract in volume until it freezes where further contraction is intuitively expected. Thus the solid is expected to be denser than its liquid and sink in the liquid. Except for water and a few other substances (including the elements silicon, germanium galium, arsenic and bismuth), this expectation is realized and the solid sinks in its liquid state (consider what would happen to lakes in the winter if water behaved like almost all other substances).

You have seen the ice-water system countless times. However, as discussed in Station 17, observation is the key to good science. A good observer would ask the question why does the ice float but very few of us have asked this question and we need to learn to make more complete observations. The question why ice floats in liquid water (why ice is less dense than liquid water) is a difficult one but inspection of the figures below reveals that water molecules are closer together in the liquid state than in the solid state.





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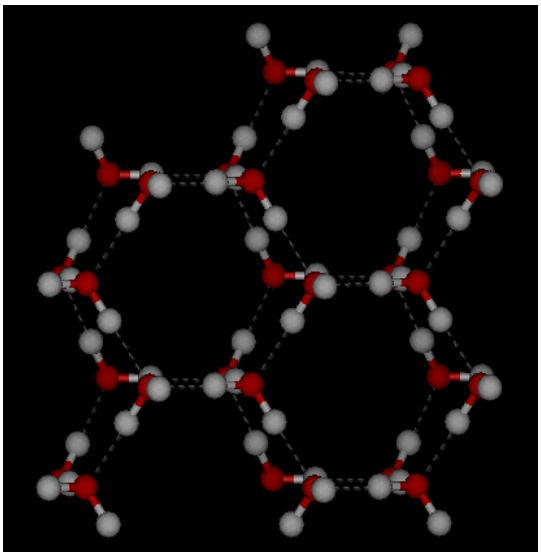

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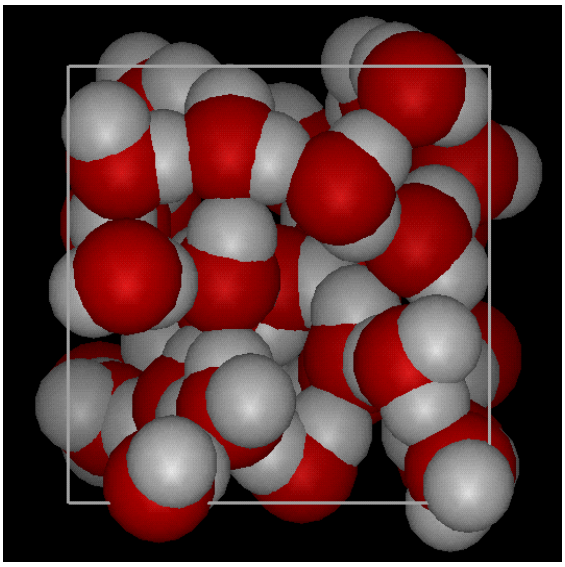
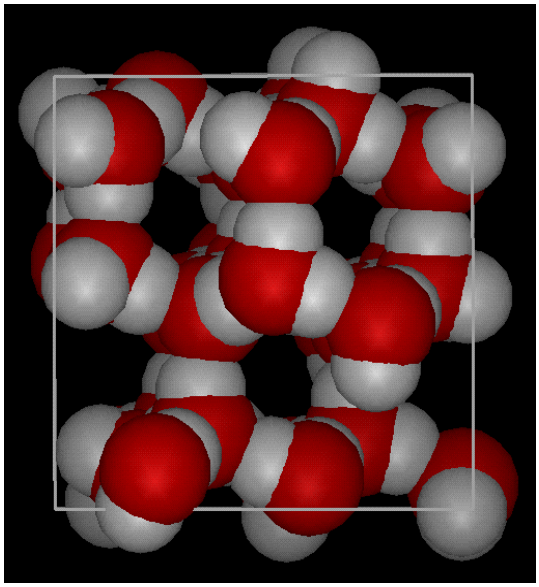
LIQUID WATER ↕



http://www.nyu.edu/pages/mathmol/modules/water/wat_10A.gif

↗
SOLID
WATER
(ice) ↘



http://www.nyu.edu/pages/mathmol/modules/water/ice_10A.gif

Station 1 - Answers to questions.

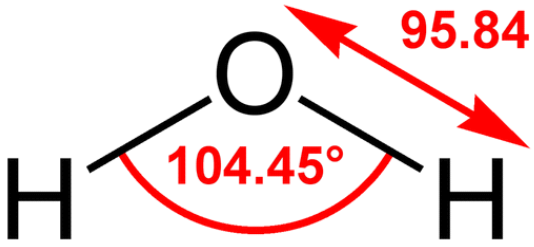
acetophenone	dioxane	water	*p*-xylene	acetic acid	oleic acid
20^{0}C	12^{0}C	0^{0}C	14^{0}C	17^{0}C	14^{0}C

The temperatures are the melting points of each substance and also the temperature at which the liquid and solid of the substance can coexist.

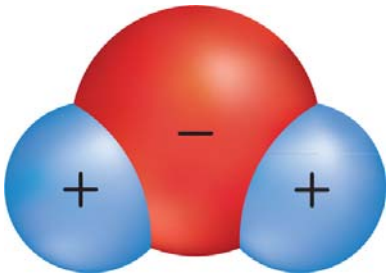
Of the six substances, only for water does the solid (ice) float in its liquid. This behavior is counter to expectations as the density should increase as the temperature decreases. This expectation is realized for almost all substances except water. However, of the millions of substances that have been characterized, the only substance commonly encountered where the sink or float question can be easily observed is water. Most people accept the abnormal behavior of water as the norm and do not question what is a very unusual behavior. For good observations, questions need to be asked as the unexpected often leads to important discoveries and advances.

If water behaved as almost all other substances behave, lakes in cold regions would still freeze on top first as it is much colder above the lake than at its bottom. However, if ice were denser than water, the newly formed ice would quickly sink and the freezing sinking cycle would repeat until the lake becomes solid ice. A completely frozen lake would limit the types of life that could survive the winter in the lake and life on earth would undoubtedly have evolved in a considerably different fashion.

4. Bonus question -



= 9.6×10^{-11} m
= 3.8×10^{-9} inches
= teeny, tiny!!



Very approximately, the test tube has about 18 mL or 18 grams of water. This is about 1 mole of water or $6.x10^{23}$ molecules (Avogadro's number).

600,000,000,000,000,000,000,000 molecules

This many regularly sized marshmallows would cover the surface of the earth to a depth of about 120 miles or the United States to a depth of 6000 miles. In other words, atoms and molecules are extremely small.