Floating Fahrenheit

Make a Galilean thermometer

Materials

small, watertight tubes
I used 2ml freestanding microcentrifuge tubes
parafilm or "press and seal" wrap
sand
empty water bottle
91% isopropanol
thermometer

scale – the more precise the better
colored pencil
cups or beakers to make warm and cold water baths

To do and notice

1. Fill a beaker with isopropanol. Determine the amount of sand that needs to be added to the tube for it to be neutrally buoyant in the isopropanol. It should just barely float or sink when put in the beaker.

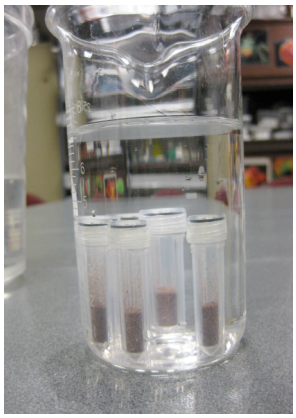
2. Measure the mass of this tube, and make 5-6 more that are within 0.04g of that mass. For examples, all of the 2ml tubes I used were between 3.18g and 3.22g after being filled and sealed. Seal all of the tubes with parafilm so that they are airtight.

3. Prepare a cold bath that will keep a beaker of isopropanol around 50ºF and a warm bath that will keep a beaker of isopropanol around 90ºF.

4. Test your sample tubes by putting them in the cold beaker of isopropanol and seeing if they float. If they don't, remove the slightest amount of sand until they do (you will have to unseal and reseal them). When they do, put them in the warm isopropanol and see if they sink. If they don't, add the slightest amount of sand until they do. Successful tubes should float in the cold and sink in the warm beakers. Make more tubes if you need to.

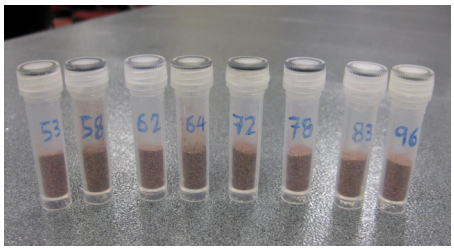
5. When you have 4-6 tubes that have the right amount of sand, place them all in the warm beaker of isopropanol. Take that beaker out of the warm bath and begin to cool it first at room temperature and then in the cold bath.

6. As the isopropanol cools, the tubes should rise when the surrounding liquid becomes more dense than they are. As each



individual tube rises, take the temperature of the surrounding liquid and mark it on the tube with a colored pencil.

7. After all the tubes have risen and have been marked, fill a plastic bottle with isopropanol. Add the tubes. They should float or sink depending on the temperature of the isopropanol.



What's going on?

Galilean thermometers use density and buoyancy to measure temperature. The density of a liquid generally decreases with increasing temperature, and the amount that the density changes is determine by the liquid's coefficient of thermal expansion. Isopropanol has a higher coefficient of thermal expansion than water, which means its density changes more for a given change in temperature. Filling each tube with a slightly different amount of sand gives them all a slightly different density since they have the same volume. Whether the tubes float or sink in a liquid the serves as a sort of "density meter" inside the thermometer. By testing the tubes in the cold and warm beakers of isopropanol, you ensured that their overall density was within the range of the density of isopropanol between 50ºF and 90ºF. As the warm beaker of isopropanol cools, its density slowly increases. When that density becomes greater than that of one of the tubes, that tube will begin to float. You can take the temperature of the bath of determine what temperature that tube corresponds to. When all of the tubes are together in the Galilean thermometer, you can look to see the lowest temperature tube that is floating and the highest temperature that is not. You then know that the temperature of the surrounding fluid is between those two values.