4S Archimedes' Test for Density

Density, or specific gravity of minerals is important in separating them. It is important to have a test for the density of mineral samples found at Snailbeach. Galena is very dense, and Barytes is much denser than other rock forming minerals such as quartz or calcite.

Below, there is the traditional story of how this test for density was discovered by Archimedes, and a set of questions about density.

Measuring Density

You will need

1. An electronic scale as used for cooking which can be zeroed after a weight is placed on the weighing pan. Measurements should be in grams throughout.
2. A glass jug half full of water. Mineral samples will need to be submerged completely without spilling the water.
3. Cotton thread tied round each specimen to be tested, so that it can be lowered into the water.

METHOD

1. Turn on the scale and then place the jug of water on it. It will weigh the jug and its contents. Zero the scale so that the next object will be measured. The weight of water and jug is not recorded.
2. Using the cotton thread, lower the sample into the water, so that it is completely covered but not touching the bottom of the jug. Most of the weight is still held by the thread, and the water level has risen. Because most of the weight of the object is still supported by the thread, what is measured on the scale is the weight of water displaced. Because one gram of water occupies one cubic centimetre we now know the volume of the sample. Write down this number, using a copy of the table below.
3. Without resetting the balance, lower the sample until it rests on the bottom of the jug. A new weight will be recorded. This is the weight of the sample, and is recorded on the table.
4. The density is the weight divided by the number of cubic centimetres the sample occupies. Using a calculator divide the weight of each sample by its volume.

Test a number of 'known' materials such as copper, lead, steel etc. as well as mineral samples. Note that it will only work with solid objects that have a higher density than water. Because it may be difficult to find pure samples of any mineral, the density may not be exactly as predicted. Record the results on a chart like that below.

Table for results of tests on different materials

Material	**Volume** (weight when suspended)	**Weight** (when resting in the jug)	**Density** (Volume divided by weight)
Weight from scale balance (as a sample)	28 c.c.	200 grams	7.149
Brass (balance weight)			
Lead			
Steel			
Aluminium			
Chalk			
Stone			
Brick			
Mineral sample A			
Mineral sample B			
Mineral sample C			

Archimedes' Discovery

In 250 B.C. Hiero, king of Syracuse (in Sicily), gave a jeweller a bar of gold to make a crown. When the jeweller delivered the crown to the king, the king measured the mass of the crown and found that the crown weighed the same as the gold he had given the jeweller. Even so, Hiero was suspicious. He believed that the jeweller had cheated him and substituted some less precious metal for the gold. Hiero asked Archimedes, a natural philosopher, to find a way to discover whether the crown was pure gold or not.

The King gave Archimedes some rules.

- Archimedes could not damage the crown in any way.
- He could not melt down the crown to see if it was made of other metals.
- He could not scratch the crown to see if there was silver underneath the golden outside.

According to legend, Archimedes struggled with the problem for a very long time. He knew that gold has a higher density than any other metal, but how could he measure the volume of a crown? Then, one day, as he stepped into a bathtub filled to the brim with water, he saw that the water overflowed. He noticed that the amount of water that overflowed the tub was proportional to the amount of his body that was submerged. He had found the answer and ran, still quite naked, from the bathhouse crying, 'Eureka!' which means 'I have found it!'

Archimedes' Reasoning

Archimedes reasoned that (1) if the gold bar and the crown had the same mass and (2) if both had the same volume, then the crown was indeed pure gold. Archimedes reasoned that the volume of water displaced by the crown should be the same as the volume of water displaced by the bar of gold. However, if the gold bar and the crown were the same mass but had different volumes, then he reasoned the crown was not pure gold, and the jeweller was a cheat.

What Archimedes Measured

Archimedes did not have an accurate electronic balance. Nor did he have a precise way to measure the water displaced from a bath full of water. His discovery, named after him as **Archimedes' Principle** states that a body immersed in a fluid experiences a buoyant force equal to the weight of

the fluid it displaces. Using this, and without an accurate set of scales, he could carry out a similar experiment to the one we have performed.

1. A large bowl is half filled with water.
2. The crown and an equal weight of gold are hung by threads, and suspended from either end of a rod so that they balance each other exactly.
3. The two objects are then lowered into the bowl of water. If the crown displaces more water than the gold it will appear to be lighter (see http://en.wikipedia.org/wiki/Archimedes) The gold will touch the bottom of the bowl whilst the crown floats.

What Archimedes Assumed

The gold crown should displace the same volume of water as the gold bar which Hiero had given the jeweller.

What Archimedes Found

Archimedes found that the jeweller's crown displaced more water than the gold block.

Archimedes' Argument (Explanation)

Archimedes reasoned that a gold crown should displace the same volume of water as the as the gold Hiero had given the jeweller. However, if it was not pure gold, but an alloy as the king suspected, that would increase the volume of the crown and displace more water. He observed that the jeweller's crown displaced more water than the gold and concluded that the jeweller's crown was not made from pure gold.

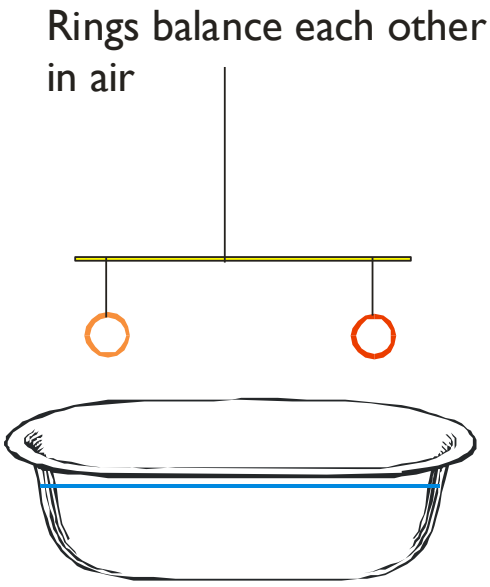
Thus, Archimedes showed that water displacement was a good method for measuring the volume of irregular objects. An object immersed in water will displace a volume of water equal to the volume of that object.

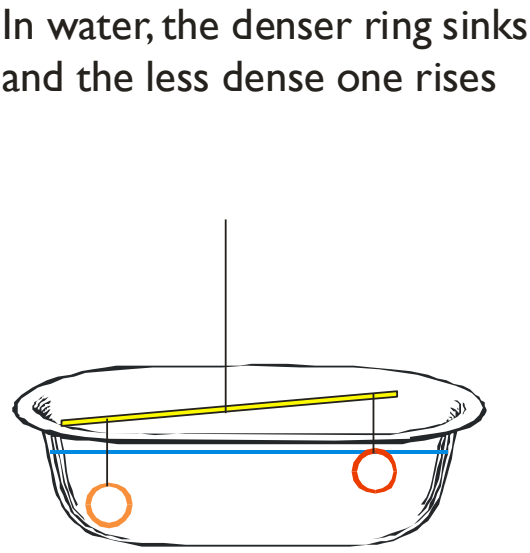
Repeating Archimedes' Test

We don't have a gold crown! But the test does need gold. You will need

1. Two gold rings of different qualities. One should as pure as possible; 18 or preferably 22 carat gold. The other could be one which is just gold plated. They do not have to be the same weight as each other.
2. A bowl of water large enough to hold the two rings when suspended from a balance, as described below.
3. A rod to act as the balance. This may be a ruler, but a round rod about 30 cm. Long may be more convenient.
4. Suspend the rod by a thread at the centre
5. Hang the rings on cotton threads at either end.
6. Move the point of balance until the rod is perfectly horizontal.
7. Now carefully lower the rings into the water.
8. The purer gold will appear to sink, and the other ring will rise.

The pure gold ring is denser than the gold plated ring. This gives an exact reproduction of the way Archimedes could have found the that the crown was not pure gold.





Questions to accompany the story of Archimedes' discovery

1) The main idea of this piece of writing is:
a) Hiero was the king of Syracuse in the third century B.C.
b) The gold crown was a fake.
c) Archimedes used water displacement to solve a problem.
d) The mass and the volume of the crown was different from that of gold.

2) Which of these statements could be understood from the reading?
a) Archimedes liked gold.
b) Archimedes was a king of Syracuse.
c) Archimedes was a great mathematician and scientist.
d) Archimedes was a jeweller and made a crown for the king.

3) About how long ago did Archimedes live?
a) 2,260 years ago
b) 250 years ago
c) 2,000,000 years ago
d) 2,000 years ago

4) What did the King want Archimedes to do?
a) Find gold.
b) Find out whether the crown was pure gold.
c) Find out if the craftsman had cheated him.
d) Both B and C

5) If you wanted to learn more about Archimedes on the internet, what key words would you use?
a) Archimedes and crown
b) Hiero and gold
c) Volume and measurement
d) Syracuse and jeweller

6) After reading the article, which would make the best conclusion?
a) Archimedes solved the king's problem.
b) Water displacement can find the volume of an object.
c) The jeweller's crown displaced more water than the gold block.
d) The king decided to hire Archimedes.

7) What does 'Eureka!' mean?
a) I have found it!
b) I have forgotten my clothes!
c) I have saved the King!
d) I have lost it!

8) Write another multiple choice question.

9) Exchange questions with a partner and answer theirs.

10) Can you think of a moment when you might shout 'Eureka!'?

What would make you shout out like this?