DENSITY

PROBLEM PRESENTATION / EXPLORATION

A. At each station students will find a number of objects that have been tightly wrapped in aluminum foil. They are told that a number of these objects are made out of the same substance, even though at first glance it might not appear so since the packages have different shapes. The CHALLENGE is to find out which ones are made out of the same substance *"without opening, removing, or tearing off the aluminum foil "* by using the equipment provided at the station.

1. At each station there should be about 8 to 10 aluminum foil wrapped packages of substances, a balance, a large graduated cylinder, and a supply of water. Each package should be labeled as A, B, C, etc.
2. Packages of the same substance should vary in mass. Don't put out more than three different substances at a station. Make sure that every package's volume can be found using the size graduated cylinder that you have provided. (If you have overflow cans, objects can be larger.) To cut down on measurement errors, your smallest samples should displace at least 15 mL of water.
3. Suggested substances:
   - a.) nails of different sizes (make sure that they are made out of the same material)
   - b.) marbles or ball bearings of different sizes
   - c.) rubber stoppers of different sizes
   - d.) pieces of limestone, sandstone, or other rocks broken into pieces of various sizes
   - e) different amounts of clay or Silly Putty®, not Play Doh®
   - f.) different sized lead sinkers
   - g.) different amounts of sand
   - h.) different amounts of popcorn kernels
   - i.) different numbers of pennies (You must use all pennies before 1982, or all pennies after 1982. The composition of a penny changed in 1982. There is about a 20% difference in weight for the same size coin)
4. Since kids will be kids, some will try to solve this problem by feeling the samples instead of finding the density as is intended. Therefore, try to package the samples to discourage this. A little of this doesn't hurt, but still, the objective is for them to identify the substance by focusing on the mass and volume of each object and realizing that there is a constant mass/volume relationship for any substance made out of the same material. Even though they may not discover this fully, it is important that they have this time to explore and gain information.
5. Provide a table in which they can record their masses and volumes or place a master chart on the blackboard.

CLASS RESPONSE / CONCEPT INVENTION

A. Each group should report back to the class on how they decided on which packages contained the same substances. Since the packages in each group are labeled the same (A, B, C, etc.), it makes it easier for the groups to follow along with each other as they report their results. After each of the four or five groups have reported, there should be consensus about which packages belong in which groups.

1. While the groups are carrying out their explorations, visit each group and try to determine which one is getting the best values for the density of their substances. Have this group record their mass, volume, and mass/volume results on a transparency and project it so that the whole class can see that for the packages classified into the same group there is a constant mass/volume relationship.
2. As each group reports, question, with mock disbelief, how they can put two

objects that obviously have different masses in the same category. Use the same questioning tactic about packages having large differences in volume. Try to get them to convince you that it is neither mass nor volume that is important, but it is the mass/volume relationship that is characteristic of a substance's identity.

3. You might finally act as though you understand this relationship but want to be sure by doing one more experiment. Ask the class if what they have been trying to convince you of means that if we would separate a long paper clip chain into a short piece and a long piece that the short piece would have the same mass/volume relationship as the long piece?. (Make a paper clip chain of at least 500 paper clips; to get the short piece disconnect about 100 paper clips from the long chain.) Carefully carry out, in front of the whole class, the mass determination and the volume determination of both the short and long pieces of the chain. Then compute the m/v ratios for both pieces. Emphasize that the m/v relationship is an identifying property of matter.
4. Only after this hands-on opportunity to see this relationship has been provided should you name this relationship as DENSITY.

B. Indicate to the class that the only type of matter for which they have found the density is a solid. Ask them how they would find the density of a liquid?

1. Have each group return to their station and determine the density of 50 mL of water. [Remind them that if they weigh the clean and dry graduated cylinder empty and then pour the liquid in up to the 50 mL mark and place the graduated cylinder plus liquid on the balance, the first mass can be subtracted from the second mass and will result in the most accurate value for the mass of the liquid.]
2. Next, have them determine the density for 50 mL of another liquid that you provide for them. (Suggested liquids: Kayro® syrup, cooking oil, rubbing alcohol, lighter fluid, Coke®, and vinegar.) Make a table showing the mass of 50 mL of the various substances. Take this time to point out that for the same volume different substances will have a different mass, in other words, they have different densities.

C. While it was relatively easy to determine the density of Coke by finding the mass of a measured volume, finding the density of soda in cans presents a slightly different problem.

1. Prepare a container of water, a bucket, a sink, or an aquarium that is at least ten inches deep.
2. Place on the table a variety of cans of soda (one regular Coke®, one Diet Coke®, one Pepsi®, one Diet Pepsi®, one RC Cola®, one Diet Rite Cola®, one 7-UP®, one Diet 7-UP®, one Sprite®, and one Diet Sprite®, or other regular and diet brands)
3. Have students place the cans into the water and make observations about the behavior of the cans.
4. Question the students about what they observed. Probably they will deduce that the regular sodas sink in water and the diet sodas float. Prod them to offer an explanation.
5. Challenge them to devise an experiment to test their explanation. Some that might be offered would be that the diet sodas don't have as much liquid inside, or that diet sodas have more gas (carbonation) than the regular sodas, or that either the regular or diet cans had been shaken before being put into the water, or that the ingredients weighed differently, or that maybe one kind had been frozen while the other kind had not been frozen, or even that the empty diet cans weigh less than the empty regular cans.
6. The beauty of this exercise is that not only do you have an opportunity to teach about density but you have a vehicle to challenge the students to design and carry out an experiment to test a hypothesis.
7. Don't give in and tell them the answer; make them prove their point and convince the rest of the class. This is a great opportunity to practice the

process skills while at the same time providing the type of event to exercise the higher level reasoning skills of analyzing, synthesizing, and evaluating.

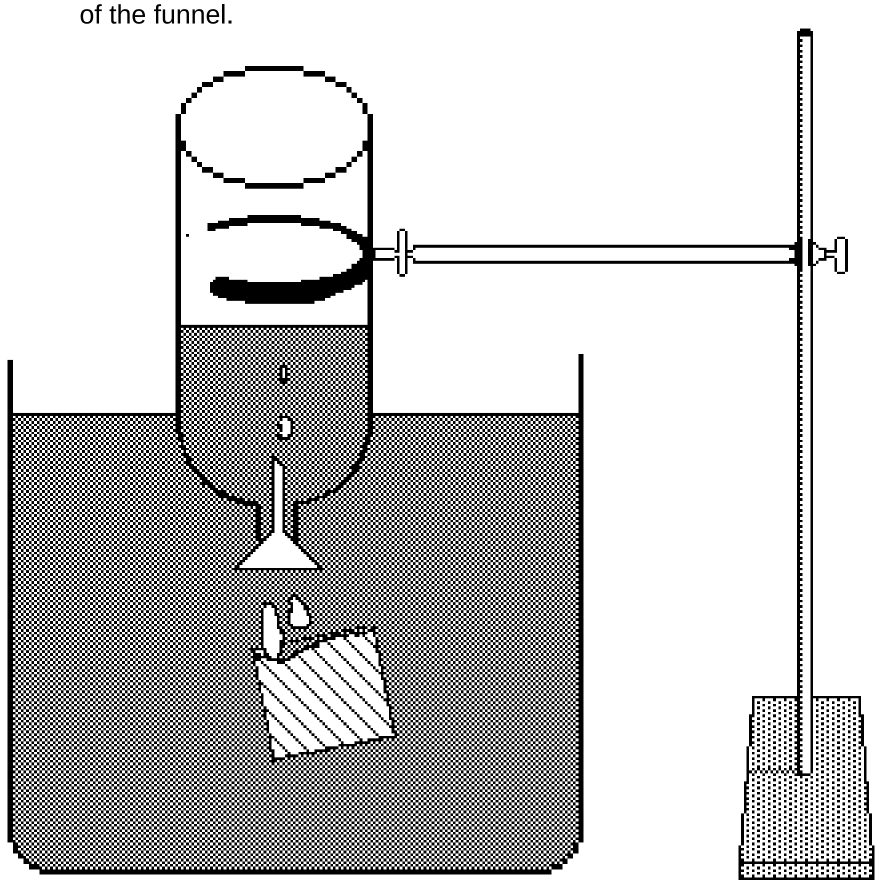
D. After the liquid densities have been determined, bring up the following problem. The density of a solid or liquid is easy to find because measuring both mass and volume can be done easily. However, how can we measure the mass and volume of a gas?

1. Demonstrate the following for the class. Start by taking an empty Ziploc® bag and putting it over the gas jet and filling up the bag with propane. If you don't have gas jets in your lab, you can exhale into the bag. Show the class that zipping the bag shut will allow us to trap a volume of gas. Point out that accurately finding the volume of the bag would be difficult, but that there **is** a neat way of doing this.

   a.) In a large sink, bucket, washtub, or aquarium filled with water, submerge and completely fill a 2-Liter Coke® bottle with water. Arrange it so that the bottle is upside down.

   b.) Submerge a large funnel in the water and allow it to rest on the bottom of the bucket, etc. Put the water-filled Coke bottle on top of the funnel so that the funnel's stem is protruding into the bottle.

   c.) Now, submerge the bag of gas and position it underneath the mouth of the funnel.

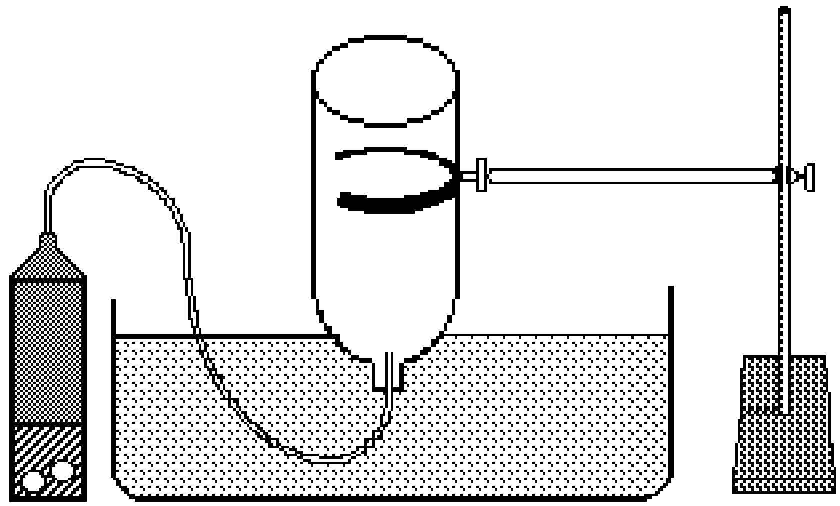


   d.) Carefully unzip the bag about one cm allowing the gas to escape. The bubbles of gas will go up the funnel into the bottle and push out water. **REMEMBER TWO KINDS OF MATTER CAN'T BE IN THE SAME PLACE AT THE SAME TIME.** Gently squeeze out all of the gas from the bag.

   e.) While the bottle is still underneath the water, screw on the bottle cap and then remove the bottle from the bucket.

   f.) Ask the class how the volume of the gas trapped in the bottle can be found. If there are no responses, say that we are interested in knowing what the gas's volume is but the amount of space doesn't have to be filled with gas. Could we find out how much water would fill that same space? Point out again that we want to know the volume and that it will be the same whether it is filled with propane, air, water, or milk. Surely someone will suggest that we simply measure how much water we would need to pour into the bottle to fill it back up and that this would be the volume of the gas. Indicate that we are simply doing the opposite of what we did when we collected the gas. Once again, since **TWO KINDS OF MATTER CAN'T BE IN THE SAME PLACE AT THE SAME TIME,** pouring in the water will force the gas to escape. This is all right, since we are only trying to get the volume that the gas had occupied **before** it escaped.

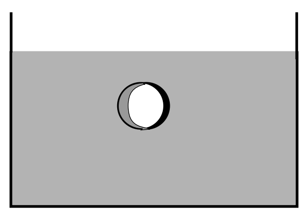
2. The next problem is how to find the mass of a gas. Don't entertain the suggestions from the class that we simply weigh a bag of gas on the balance. The reason that we don't want to do this is that the buoyancy of the air will give a false mass (too light). Instead, tell them that you know of another sneaky way that can be used to measure the mass of a gas.
   a.) Tell them to think about how the Highway Department finds out how much cargo a truck is carrying when it stops at the weighing stations on our state and federal highways. Do they take out all the cargo and put it on the scales? No! Painted on the side of the truck is its EMPTY MASS. Then by driving the truck onto the scales and finding its TOTAL MASS and subtracting its EMPTY MASS they can find the mass of the cargo.
   b.) Tell them that we are going to do the same kind of thing for finding the mass of the gas that comes out of two Alka-Seltzer® tablets when they are put into water. Tell them to attach a rubber hose to the nozzle of a plastic squeezable catsup bottle. After adding 50 mL of water they are to weigh the apparatus (bottle + rubber hose + water). Also they are to separately weigh two Alka-Seltzer® tablets. By adding these two masses together we will get the TOTAL MASS of our system. Next, the rubber hose should be inserted into the submerged 2 L bottle. The Alka-Seltzer® tables should be dropped into the catsup bottle and the lid quickly snapped on. The gas can now can be collected in the 2 L bottle by displacing a volume of water equal to the volume of gas generated. After all the gas has been collected, the mass of catsup bottle + rubber hose + 50 mL of water + what is left over from the Alka-Seltzer® tablets should be determined and will be called the EMPTY MASS.



c.) Now by subtracting the EMPTY MASS from the TOTAL MASS we will obtain the mass of the gas generated. The density of the gas in Alka-Seltzer® can now be determined by dividing mass by volume. [*The density should be greater than 1.5 g/L using this technique*.]

CONCEPT EXTENSION

A. We have seen that equal volumes of different liquids have different masses. We have learned to say that this means that different substances have different densities. Have the students imagine a bucket of water where a 50 mL hole has been carved out of the middle of the water.



What would happen if we put the 50 mL of the various substances that we have been working with into this hole? Would this 50 mL sink or rise? Predict what would happen in the table below.

Substance (50 mL)	Sink	Rise
Kayro Syrup	√	
Cooking Oil		√
Sand	√	
Alcohol		√
Lighter Fluid		√
Pennies	√	

Notice the densities of the substances that sank. Notice the densities of the substances that rose. (Refer back to Concept Invention, section B2.) What relationship is there between the density of an object placed in a fluid and the density of that fluid and whether the object will sink or float? [*Substances that have densities greater than the density of the liquid in which they are placed sink. Substances that have densities less than the density of the liquid in which they are placed rise upward to the top of the liquid. If an object had the same density as the liquid that made up* *the hole it would remain suspended between the top and bottom of the liquid in which it was placed.*]

B. Imagine a bucket of air instead of water. Once again imagine carving out a 50 mL hole. What would you suspect would happened if we filled the hole with other gases? [Reemphasize: *Substances that have densities greater than the density of the liquid in which they are placed sink. Substances that have densities less than the density of the liquid in which they are placed float.*] What would have to be true if the gas would float upward? What would have to be true if the gas sank downward? Instead of carving out a hole, what if we had a weightless balloon full of different gases and we suspended them in a room full of air? Which would rise? Which would fall? The density of air is about 1.29 g/L, therefore, if the mass of 1.0 L of our experimental gas is heavier than 1.29 g, it will fall. If it is less than 1.29 g it will float upward. Have students predict the outcomes in the following chart based upon the gas's density. The densities of many of these gases can be looked up in various references. The best one is the *Chemical Rubber Corporation Handbook of Chemistry and Physics*. There is one at the public library in case you don't have one in your school library.

Substance (1.0 L)	Mass (g)		Rise	Fall	Density (g/L)
	> 1.29 g	< 1.29 g			
Air					1.29
Butane**	√			√	2.59
Carbon Dioxide	√			√	1.97
Exhaled Air	√			√	
Helium		√	√		0.179
Hydrogen		√	√		0.089
Methane***		√	√		0.714
Oxygen	√			√	1.43
Propane****	√			√	1.97

C. Even though there is no such thing as a weightless balloon, we can approximate this by filling soap bubbles with the various gases and checking the predictions.

1. Obtain some gas in a balloon. Prepare the Bubble Blower by attaching a funnel to one end of a piece of rubber hose Attach the other end to the balloon. If the funnel is dipped in a soap solution* and then the gas in the balloon is forced out, gas will flow through the funnel and form bubbles containing the various gases instead of air. Observation will then confirm whether the density is >1.29 g/L or < 1.29 g/L.
2. If you have difficulty getting the gas into a balloon, a large syringe may be used instead. First, collect the gas by water displacement into any glass container. Prepare the syringe by closing the plunger, removing the needle, and replacing the needle with a length of rubber tubing. With the bottle of gas still submerged in the water, stick the rubber tubing into the bottle of gas and slowly pull up the plunger to fill the syringe with gas. Now fill the soap bubbles with gas by attaching the funnel dipped in soap solution to the rubber tubing and slowly pushing the plunger back in. (If you can't find a syringe, a bicycle pump might be used.)
3. (*) A recommended soap solution can be made by mixing 300 mL water, 85 mL Joy liquid detergent, and 15 mL glycerin (also known as glycerol and can be purchased at a drugstore). This produces a "tougher" bubble that is more conducive for study.
4. (**) A very easy way to collect a bottle of butane is to take a Bic® lighter and submerge it in water. When you "flick the Bic®" a bubble of butane will begin to rise. Capture this bubble by placing a glass bottle filled with water over it.

The butane will displace the water. Because this may be slow there is a faster way that you might get some butane. Into a Ziploc® bag spray some aerosol product that is propelled with butane or isobutane. The bag will get very cold and after a few seconds liquid butane will collect in the bag. Upon gently warming the liquid, butane will vaporize and start to fill up the bag. Butane-filled bubbles can then be collected.

5. (***) Methane gas can be produced mixing equal amounts of **solid** anhydrous sodium acetate and sodium hydroxide and placing them in a large DRY test tube.. Fit the top of the test tube with a stopper and a gas delivery tube. Carefully heat the test tube and collect the methane by water displacement. <u>Care should be taken with open flames in the vicinity of methane since it is flammable</u>.
6. (****) LP cylinders can be cheaply purchased at places like Wal-Mart or K-Mart.

D. As a final challenge have students propose ways in which they could "accurately" determine the density of an ice cube.

1. On the surface this looks like the straightforward problem encountered in Problem Presentation phase of this lesson. However, when the ice cube is placed on the balance, some of it will have melted and an accurate weight will not be obtained. Furthermore, trying to "accurately" find the volume of the ice cube presents another problem. If it is placed in water, its entire volume is not displaced. If put in something like alcohol, where it does sink, it melts appreciably giving an erroneous volume.
2. It should be interesting to see what ingenious ways students will think up to overcome these problems. The key lies in the idea presented in part A of the Concept Extension. <u>*If an object had the same density as the liquid that made up the hole it would remain suspended between the top and bottom of the liquid in which it was placed*</u>.
3. Someone may stumble across a very clever way to obtain this density while observing that ice cubes really do sink in alcohol. If the ice cube is placed in a relatively small amount of rubbing alcohol, it will sink. If left there, it can be seen that it indeed does melt. Depending on the size of the ice cube and the quantity of alcohol, after awhile the ice cube will start to float upward!! Upon agitation it will probably sink again, but soon will rise again. The obvious question to pose is WHY?
4. This phenomenon can be viewed without having to wait for it to happen by itself. If we carefully add water to the alcohol/ice cube mixture we will cause the density of the resulting solution to fall somewhere between the density of pure water and pure rubbing alcohol. At the point that the ice cube is suspended equally between the top and bottom of the glass the density of the liquid mixture must be the density of the ice cube! Now all that must be done is to pour out some of the liquid mixture and determine the mass of say 50 mL of it. This mass divided by 50 mL will give the density of the ice cube in g/mL.