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Archimedes and the Golden Crown

In the first century BCE King Hiero desired a new crown. The king went to a goldsmith in town and said, "I desire for you to create for me the most beautiful, regal crown that will show everyone my great wealth and power." The goldsmith accepted the job and the king gave him the bars of his finest gold that the goldsmith would need to make such an exquisite crown. Time passed and the king awaited his fabulous new crown, but one night the king had a dream. In his dream the king saw the goldsmith stealing some of his gold and replacing the stolen gold with a cheap metal to make the crown. The king awoke in a tizzy. He had to make sure that the crown was truly made out of the finest gold in the kingdom.

In his desperation the king called for his royal scientist, Archimedes. "Archimedes", the king said, "I need to you make sure that the goldsmith has really used all the gold I gave him in the crown". Archimedes pondered this for a while, and decided that he could just weigh the crown when it was delivered to the king and make sure that the crown had the same mass as the original amount of gold given to the goldsmith.

The next day the goldsmith delivered the crown to the king with Archimedes waiting to balance the crown and the weight of the original gold. Upon weighing the crown and the gold Archimedes discovered that they did indeed share the same mass, but Archimedes had a bad feeling about the crown and the goldsmith. He thought to himself, "There must be another way to prove the crown isn't pure gold! If only I could melt down the crown and make it into a cube so I could calculate the volume of the crown and the volume of the gold." By using the relationship between mass and volume he could determine the density of the crown. Since density is a characteristic property it will remain the same no matter the amount of gold as long as the gold is pure. If the crown had the same density as pure gold than the crown was pure. Alas, he was unable to melt down the king's new crown and so he had to find a new solution.

Frustrated by this problem Archimedes decided to relax in a bath. His thoughts distracted him from watching the water fill the bath tub and Archimedes stopped the water right as it was about to splash over the side. He stepped into the tub and watched as water spilled over the top of the tub and onto the floor. Suddenly watching the water Archimedes realized the solution to his problem! "EUREKA!" He shouted as he leapt out of the tub and ran through the streets of the kingdom to share his solution with the king.

Archimedes had realized that he could calculate the amount of water displaced by the crown and the amount of water displaced by the gold to determine their volumes, and therefore their densities! So with this new strategy to solve his problem Archimedes called for a large bucket of water and determined.....we're about to do our own investigation to find out.

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Part One- Calculating Density

To complete part one calculate out the mass, volume, or density based on the equations or situations below using the density formula given. **Show your work and write the density formula at the start of each problem.**

$$density = \frac{mass}{volume}$$

1. Determine the density of a substance with a mass of 3g and a volume of 12mL.
2. Determine the density of a substance with a mass of 15g and a volume of 7mL.
3. Determine the mass of a substance with a density of $3 \frac{g}{mL}$ and a volume of 9mL.
4. You are cooking dinner and your sister is doing laundry. She has pre-measured bleach to clean with and you have pre-measured your water to cook with. The cup with bleach and the cup with water have been mixed up and you must determine the density of each in order to make sure that bleach doesn't end up in your dinner.
In cup A you have a liquid that has a mass of 10g and a volume of 10mL. In cup B you have a liquid that has a mass of 10g and a volume of 9g. The density of **bleach is $1.11 \frac{g}{mL}$** and the density of **water is $1.0 \frac{g}{mL}$** . Which cup contains bleach and which cup contains water?

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Cup _____ contains bleach

Cup _____ contains water

Part Two- Testing the crown

Now is your chance to see if the goldsmith is trust worthy. Take the “crown” and “gold” at your table and make observations of two physical properties and determine the mass and the volume of each. Then calculate the density of each and determine if you believe that the crown is pure gold or not.

	<u>Observation</u>	<u>Observation</u>
	<u>1:</u> _____	<u>2:</u> _____
Crown		
Pure Gold		

	<u>Mass</u>	<u>Volume</u>	<u>Density</u>
Crown			
Pure Gold			

Conclusion: I believe that the crown was _____.

Summary

1. Did your group determine the crown was pure gold or a fake? Why did you come to this conclusion? What observations and calculations did you make in order to come to this conclusion?

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2. Explain the role that density plays in identifying unknown substances.
3. What makes characteristic properties different from other physical properties? What makes physical properties including characteristic properties different from chemical properties?

Analysis

1. Many forensic scientists like those seen on shows like CSI and NCSI trying to determine what happened at crime scenes rely on the existence of characteristic properties like density to help them do their jobs. Why are characteristic properties so important to forensic scientists?
2. The temperature at which substances change states of matter (boiling and melting points) are also characteristic properties. When you go to many recipe websites you have the option to adjust the serving size so you can choose how much food you would like to make. Why is it important that boiling point is a characteristic property for adjusting amounts of food in a recipe? (Hint: think about how we make pasta or cover things in chocolate)

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