What Is the Elemental Composition of Those BBs? ("don't let it fool ya about what's inside")

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16 minutes for this section

Information: Density is a physical property commonly used to identify the composition of a substance. Density is calculated by dividing the mass of a substance by its volume. $\left(density = \frac{mass}{volume}\right)$. Common units are grams/milliliter (g/mL) or grams/centimeters^3 (g/cm^3).

Model 1: Is that painted metal cylinder worth anything?

Volume (cylinder) = $\pi r^2 h$

Key Questions:

1. What color is each cylinder? orange
2. Do you know for certain the actual composition of the cylinder from its color? No
   Explain why or why not.

Things can have a different color, but be a different substance. We can paint things to be any color even if that's not what it is naturally

3. Using the information in the model, fill in the table and calculate the volume for each cylinder.

	Cylinder #1	**Cylinder #2**
Mass (g)	2233	776
Radius (r)	2.9	5.18
Height (h)	4.38	3.41
Volume (cm^3)	115.7	287.5

4. Now, determine the density (density = mass/volume) of each cylinder. You *must* show the work for your calculations.
   Density of Cylinder #1: 19.3 Density of Cylinder #2: 2.7

$$\frac{2233}{115.7} = 19.3$$

$$\frac{776}{287.5} = 2.7$$

Density (g/cm³)	Material
0.92	Canola oil
1.00	Water
2.26	Graphite
2.70	Aluminum
7.13	Zinc
7.87	Iron
8.96	Copper
11.3	Lead
19.1	Uranium
19.3	Gold

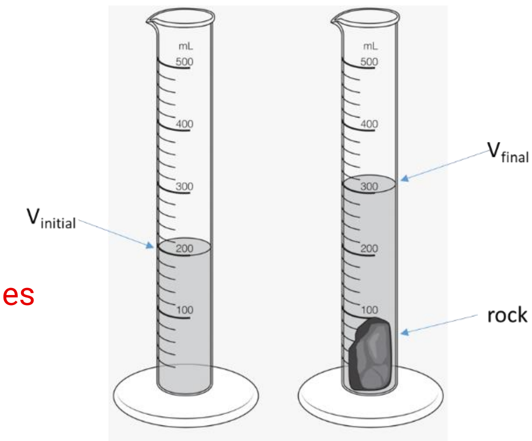
5. With the densities determined above, use the table to identify the composition of each cylinder.
   Cylinder #1: Gold
   Cylinder #2: Aluminum
6. Which cylinder clearly has a high monetary value?

   Cylinder #1

Exercises:

7. A rock is placed in a graduated cylinder filled with some liquid as shown below.

   a. Examine the rock placed in the graduated cylinder on the right. Why would it be difficult to calculate the volume of the rock by direct measurement as was done for the cylinders above in the model?



It's a weird shape with random curves and uneven sides

   b. What is the volume of the water in the graduated cylinder without the rock placed in it ($V_{initial}$)? 200 mL What is the volume of the water in the graduated cylinder when the rock is placed in it (V_{final})? 300 mL

   c. Determine the volume of the rock. You must show your work.

   100 g/mL

   d. The mass of the rock was determined to be 351.2 g. What is the density of the rock? You must show the work for your calculation.

$$\frac{351.2}{100} = 3.512$$

8. You found a liquid on a shelf in the kitchen which is unlabeled. You want to dump it down the sink, but you don't know if it's hazardous. The liquid is clear, and you think it's water. Knowing the density can help you determine the identity. Describe a method to determine the density of the liquid.

Measure an amount of liquid and weigh it, then divide its mass by the volume to determine the density of it

Entire class discussion:

Method development:

Items needed for *each* member of the group: 50 mL graduated cylinder, ruler, container of brine solution (1 container per group, on first bench), and wood cylinder.

9. Examine the graduated cylinder. In which place is the estimated digit? Tenths place
   Examine the ruler. In which place is the estimated digit for the centimeters? Hundredths
10. Examine the brine solution. Describe a method to determine the density of this liquid.

    Measure out some liquid and get its mass, then divide the mass by the volume

11. Examine the wood cylinder. Describe a method to determine the density of this regular solid.

    Measure the radius and height then calculate the volume from that, and then weigh it to get the mass. Then divide the mass by the volume

12. Examine the metal shot on the first bench. Describe a method to determine the density of this metal shot.

    Measure a certain amount of water then place the metal shot in it and measure the displacement of the water

Individual data collection (each person in the group will acquire their own data):

13. Determine the density of the brine solution using a method described previously (use between 15-20 mL). Remember, always take the volume measurement at the bottom of the meniscus. Show your work for the density calculation. Make sure your measurements have one estimated digit and to consider significant figures when performing calculations. Place used brine solution in appropriately labeled container.

$$\frac{20.382g}{17.5mL} = 1.16$$

14. Determine the density of the wood cylinder using a method described previously. Show your work for the density calculation.

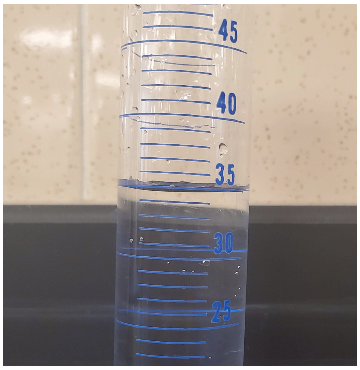
$$r = 0.75$$

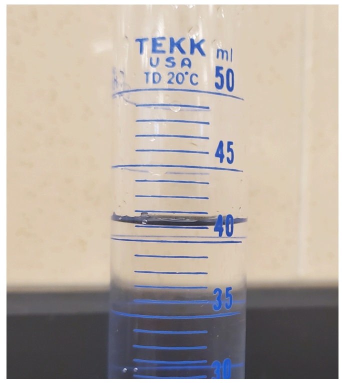
$$h = 5.00$$

$$\frac{6.108}{\pi\left(0.75^2\right)\cdot 5.00} = 0.690$$

$$m = 6.108$$

15. Determine the density of the metal shot using a method described previously. Use between 15-18 grams of the metal shot from the appropriate container. Show your work for your density calculation.
With your cell phone, take a picture of the graduated cylinder with the liquid (water) *before* adding the metal shot and one *after* adding the metal shot. Volume measurements need to come from these pictures. Put wet metal shot in the appropriately labeled container.





$$\frac{15.778}{(40.0 - 34.9)} = \underline{3.09}$$

<u>Compilation of group data and group analysis</u>:

16. In the table below, input the density of the brine for each group member (including your own) and then calculate an average for your group.

	Density of brine solution
Group member	1.16
Group member	1.18
Group member	1.14
Group member	1.19
AVERAGE DENSITY	1.17

17. In the table below, input the density of the wood cylinder for each group member (including your own) and then calculate an average for your group.

	Density of wood cylinder
Group member	0.690
Group member	0.77
Group member	0.86
Group member	0.68
AVERAGE DENSITY	0.75

18. In the table below, input the density of the metal shot for each group member (including your own) and then calculate an average for your group.

	Density of metal shot
Group member	3.09
Group member	2.40
Group member	2.50
Group member	2.41
AVERAGE DENSITY	2.60

19. Are the density values determined by your group members precise? Explain how you made this determination. If the density values aren't precise, suggest a reason.
    - Brine solution Precise? Yes

      Only the estimated digit is different between our measurements

    - Wood cylinder Precise? No

      The density might not be completely consistent for all our wood cylinders, or read the ruler differently

    - Metal pieces Precise? No

      One measurement was off, but the other 3 were precise. It could have been misread measurements or could have been air bubbles in the water

Class data: In the class data sheet (link in Canvas), input the average values.

Information: A common type of air gun shoots small spherical projectiles called BBs. You will see below that there are various types of BBs.

<u>Method Development:</u>

<u>Items needed for *each* member of the group:</u> 50 mL beaker and 50 mL graduated cylinder.

20. Examine the BBs in the containers (there are two different types). Which method form above would be a wise choice to determine the density of the BB's? Why did you choose this method?

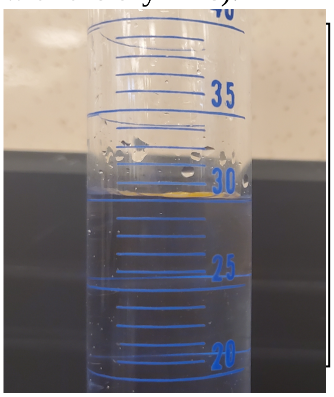
    The method of putting them in water and measuring the displacement

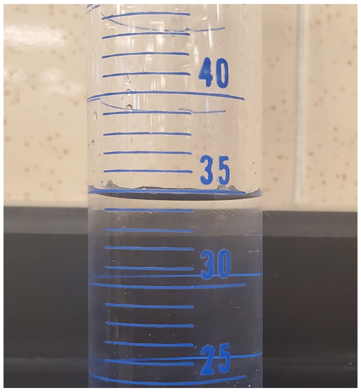
21. Based on the appearance of the BBs, propose a primary *element* (e.g., iron, copper, gold, zinc, aluminum, etc.) of each type of BB.

BB#1: Copper BB#2: Iron

Individual data collection (each person in the group will acquire their own data):

22. Determine the density of each type of BB. Show your work for the density calculations. Note: Use 35-37 grams of each type of BB from the appropriate container. For BB#2, take a picture of the graduated cylinder with the liquid (water) *before* adding the BBs and one *after* adding the BBs. Volume measurements need to come from these pictures. Dispose of wet BBs in the appropriately labeled container (*not* the container with the dry BBs).





- Density BB#1 (color: copper) 7.87 g/mL

$$\frac{36.224}{34.5 - 29.9} = 7.87$$

- Density BB#2 (color: silver) 7.50 g/mL

$$\frac{36.003}{(34.8 - 30.0)} = 7.50$$

Compilation of group data and group analysis:

23. In the table below, input the density of each BB type for each group member (including your own) and then calculate an average for your group.

	Density BB#1	Density BB#2
Group member	7.87	7.50

Group member	8.3	7.8
Group member	7.60	7.27
Group member	8.0	7.38
AVERAGE DENSITY	7.94	7.49

Ask the teacher or lab assistant to check your work for the calculations above before proceeding.

24. Are the density values determined by your group members precise? No
    a. Explain how you made this determination.

    The values range by quite a bit for several of them

    b. If the measurements aren't precise, suggest a reason.

    BB sizes or density may not be consistent, reading measurements differently or rounding in calculating

25. Based on your group's density data, suggest the primary element that makes up each type of BB (see table above with density values).

BB#1: Iron BB#2: Zinc

26. Refer to the title of the lab, "*don't let it fool ya about what's inside*". Were you fooled about what's inside when examining the appearance of the BBs?

    Yes

27. There is obviously a thin shell of an element surrounding the BBs. Suggest a purpose for this thin shell.

    Whatever is on the outside may hold it together better, and not crumple as much when hitting something. Also cost efficiency

<u>Class data</u>: In the class data sheet (link in Canvas), input the average values for the BB's.

Information: A solution in which salt is dissolved in water, the percent mass of the salt in the solution is calculated with the following formula.

$$\frac{mass\ salt\ (g)}{mass\ salt\ (g) + mass\ water\ (g)} \times 100.0\%$$

<u>Method Development:</u>

Items needed for *each* member of the group: 50 mL beaker, scoopula, 10 mL graduated cylinder, table salt (one container per group, on first bench).

28. Calculate the percent mass of salt when 23.0 grams of salt are dissolved in 75.0 grams of water. Show your work and consider significant figures.

$$\frac{23.0}{23.0 + 75.0} \cdot 100\% = 23.5\%$$

29. There is a maximum percent mass when salt is dissolved in water. Explain why this is true.

    Once a certain limit is reached, the water cant dissolve any more in it, so the percent mass would also have a limit

30. Predict how the density of a solution will change as the percent mass of the salt increases (see equation above).

    It will increase. You're adding more mass to the same volume

31. You are going to make a salt solution and determine the percent mass of the salt. Describe a method to make this solution and how the percent mass will be determined.

    Dissolve salt in water. Measure the mass of the salt before dissolving and mass of the water before dissolving to calculate the percent mass after dissolving

Ask the teacher or lab assistant to check your work for the calculations above before proceeding.

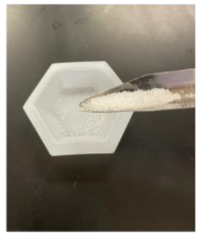
Individual data collection (each person in the group will acquire their own data):

32. The below information will assist you in setting up the equipment to make the appropriate table salt solution and determine its percent mass and density.
    a. Determine the mass of a clean, dry 50 mL beaker (place in the table below).
    b. Add water to the beaker until near the 10 mL mark on the 50 mL beaker and record the mass.
    c. Determine the mass of the water in the beaker by subtraction. This value should be close to 10 grams. If it is not, add or remove water.
    d. Make a specified salt solution in the 50 mL beaker with the added water. Each member of your group will make a salt solution with a different concentration (percent mass). A group member will have to do more than one if you only have three in your group. Make assignments and circle the mass (or masses) you will be using.
        i. Approximately 1.0 g NaCl
        ii. Approximately 1.5 g NaCl
        iii. Approximately 2.0 g NaCl
        iv. Approximately 2.5 g NaCl

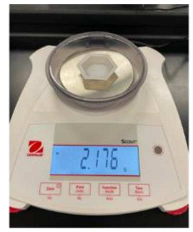
e. Measure out the amount of NaCl using a weigh boat and record the mass from the balance (see technique below).

Weigh boat

Mass weigh boat only



Remove weigh boat and add NaCl



Mass of weigh boat and NaCl

Remove weight boat and add or remove NaCl until appropriate mass is obtained.

Mass of 50 mL beaker	30.938
Mass of water and beaker	40.939
Mass of water	10.001
Mass of NaCl	2.007

f. Transfer the sodium chloride to the water in the 50 mL beaker and stir until dissolved.

g. Calculate the percent salt of the salt solution. Show your work.

$$\frac{2.007}{2.007 + 10.001} \cdot 100\% = 16.71\%$$

h. Determine the density of your salt solution using a 10 mL graduated cylinder (use between 7.0 and 7.5 mL of your solution). Show your work. Be sure to measure your volume to the estimated digit on the graduated cylinder. <u>Note:</u> You will need to determine both the mass and the volume of your solution in the 10 mL graduated cylinder.

$m = 8.012$

$v = 7.30$

$$\frac{8.012}{7.30} = 1.10$$

Your salt solution may be poured down the drain.

<u>Compilation of group data and group analysis:</u>

33. In the table below, input the density and percent salt for each group member.

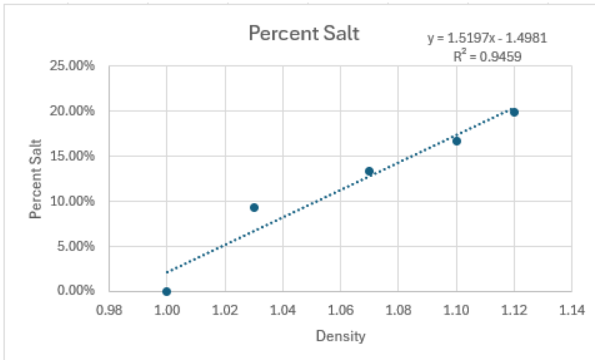
	Density (g/mL)	**Percent salt**
No NaCl added	1.00	0.00
Approximately 1.0 g NaCl	1.03	9.39

Approximately 1.5 g NaCl	1.07	13.40
Approximately 2.0 g NaCl	1.10	16.71
Approximately 2.5 g NaCl	1.12	19.90

34. What is the correlation between density and percent salt?

The higher the percent salt, the higher the density

35. Using Excel, each group member will create an XY scatter plot of your group's data (X variable is density). Add a linear trendline to the data. If one of the points looks far off the line, perform this concentration again.
    a. What is the equation for your line? $y = 1.5197x - 1.4981$
    b. What is the R^2 value? 0.9459
    c. With your cell phone, take a picture of your XY scatter plot. This picture needs to display the equation and R^2 value for your line.



    d. The equation you just determined from your Excel graph is called a calibration curve and can be used to calculate the concentration of any salt solution with a known density. Use your equation to determine the concentration of the brine solution (saturated salt solution) whose density was measured earlier in the lab. Show your work below.

$$(1.5197\,(1.16) - 1.4981) \cdot 100\% = 26.48\%$$

<u>Class data</u>: In the class data sheet (link in Canvas), input the trendline equation and R^2 value for your group.

Make sure all items are clean and return them to the drawer or bench. Finish cleaning any glassware used by rinsing with distilled water. Before you leave, ask the teacher or lab assistant to examine your data and laboratory space. Note: Your data must be entered into the spreadsheet before you leave.

<u>Application of principles (to be completed individually)</u>:

37. What is the density of a titanium sample that has a mass of 28.6 g and a volume of 6.36 mL?

$$\frac{28.6}{6.36} = 4.50$$

38. A metal sample has a mass of 15.33 g. When the sample is placed in a graduated cylinder, the water level rises from 26.7 mL to 32.4 mL.
   a. What is the density of the metal sample? You must show your work by writing below or inserting a picture of your work.

$$\frac{15.33}{32.4 - 26.7} = 2.69$$

Density (g/cm³)	Material
0.92	Canola oil
1.00	Water
2.26	Graphite
2.70	Aluminum
7.13	Zinc
7.87	Iron
8.96	Copper
11.3	Lead
19.1	Uranium
19.3	Gold

   b. Using the table of densities given above determine the identity of the metal? Aluminum

39. The density of propylene glycol (antifreeze) is 1.04 g/mL. What is the volume in mL of 4.92 pounds of antifreeze? (1 pound = 454 grams)

$$v = \frac{m}{\rho} \qquad \frac{(4.92 \cdot 454)}{1.04} = 2147.8\frac{g}{mL}$$

40. You are now going to compare your individual values with the average values of the class in the *Class Data Sheet*. Make sure the *Class Data Sheet* is complete before doing this. You will have to wait until the end of the lab period. Fill in the following table below.

	Your individual value	**Average value of class**
Density of brine solution	1.16	1.16
Density of cylinder	0.69	0.727
Density of metal shot	3.09	2.6
Density of BB#1	7.87	7.7
Density of BB#2	7.50	7.7

The agreement between a measured value and an accepted value can be analyzed by performing a percent error calculation (equation given below). For this calculation, the measured value is your individual value, and the accepted value is the class average (in Google Sheet).

$$Percent\ Error = \frac{(measured\ value - accepted\ value)}{accepted\ value} \times 100.0\%$$

   a. Calculate a percent error for each of your individual values.

	Percent error
Density of brine solution	0%
Density of cylinder	- 5.08%
Density of metal shot	18.8%
Density of BB#1	2.21%
Density of BB#2	- 2.60%

b. For each percent error greater than 5% (or less than -5%), suggest at least one reason for your individual value being significantly different than the accepted value.

Cylinder: density of everyone's specific chunk of wood may not be completely consistent, reading measurements differently, scales accuracy and consistency.

Metal shot: density or everyone's specific metal shots may not be completely consistent, air bubbles in the water, reading measurements differently, scales accuracy and consistency.