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Module 1; Density of Solids

Directions: Answer all questions in this text document. Submit your document to be graded. You may print out this document, then hand write and scan. OR you can word process directly on this document.

Introduction

Density is the mass of an object per unit volume. It is calculated by dividing the mass of an object by its volume:

$$\text{density (d)} = \frac{\text{mass (m)}}{\text{volume (V)}}$$

A large density means that lots of material is packed into a small space. The metals known as "heavy metals" are actually just more dense than other metals. For example, the density of gold at 25°C is 19.32 g/cm^3, while that of copper is 8.96 g/cm^3. In other words, a 1 cm^3 block of gold (one of the heavy metals) weighs 19.32 g, while a 1 cm^3 block of copper weighs 8.96 g.

Every substance has a characteristic density, so density can be used to determine identify substances or establish purity. Density is constant at a given temperature; hence, the need to report temperature when you report density. Some densities are given in Table 2.1.

Density can also be used to determine measurements that are too difficult to make directly. For example, in order to measure the thickness of a thin piece of foil, you need a special instrument. However, you can also determine thickness by measuring the mass, length, and width of the foil. Using the mass of the foil and the density, you can determine the volume of the foil. V = mass /density. Then you can determine the thickness (height) since the volume, V = length x width x height. [And thus, height = V/(length X width)]

Pre-Laboratory Exercise

Complete the following exercises paying attention to units and significant figures. All answers should have three significant figures (sig. figs.) since the data provided has three sig. figs. Use one of the following formulas in each case:

D = M / V   M = D X V   V = M / D

1. If the mass of an unknown piece of metal is 58.0 grams and it occupies a volume of 12.9 mL, what is the density of the metal? As always when doing a calculation, first write down the formula and then plug in the numbers *with the units*. Write your answer with three sig. figs.
   Remember, Density of solids are given in g/cm^3 in table provided, so first you must convert volume unit 'mL' to 'cm' by using relationship learned in lecture in Module 1,i.e., 1cm3 =1 mL)

$D = M/V = 58/12.9 = 4.50\ g/mL$

2. Using your answer in #1 and the information in the table below, identify the metal in question #1:

Titanium

Densities of some common metals at 25°C

Metal	Density (g/cm^3)	Metal	Density (g/cm^3)
Magnesium	1.74	Nickel	8.91
Aluminum	2.70	Copper	8.95
Titanium	4.50	Silver	10.49
Zinc	7.14	Gold	19.32
Iron	7.87	Tungsten	19.3

3. A 105 g slab of metal is dropped into a cylinder which has 69.9 mL of water in it. The water goes up to 83.3 mL with the metal slab in it. What is the density of the metal? First calculate the volume considering the water displacement data provided. Then to solve for density: write down the formula and then plug in the numbers *with the units*. Write your answer with three sig. figs. Remember, Density of solids are given in g/cm^3 in table provided , so first you must convert volume unit 'mL' to 'cm' by using relationship learned in lecture in Module 1,i.e., 1 mL = 1cm3)

volume = 83.3 - 69.9 = 13.4 mL

Density = $\frac{105}{13.4}$ = 7.84 g/mL

4. Using your answer and the information in the table above, identify the metal:

Iron

5. If the slab of metal above was actually a cylinder with a 0.600 cm radius, how tall is the cylinder? To calculate this, consider the volume you calculated in the first part of #3. Since 1 mL=1cm^3, you can use the volume you calculated in #3 with cm^3 as its units so that units will cancel out correctly. Use the formula $V = \pi r^2 h$ which rearranges to $h = V / (\pi r^2)$. Round your final answer to three sig. figs. to match the measurements.

Volume = 13.4 mL = cm^3

$V = \pi r^2 h$

height $\frac{13.4}{\pi (0.6)^2}$ = 11.8 cm

$\frac{V}{\pi r^2} = h$

Density
Procedure and Data

Use the following link to access an online simulation. Be patient; it opens slowly. Also, you will need to use the latest version of chrome, Firefox, safari or edge. If you click on this link and see empty gray boxes labeled "introduction, compare and mystery", you will need to try a different browser. Copy and paste this link into the other browser. I suggest you use a split screen so that you can follow directions while running the experiment. Or print this document and hand write your answers; then scan and submit.

Simulation link: https://phet.colorado.edu/sims/html/density/latest/density_en.html

Part 1: Water Displacement to Measure Volume

1. Select the "**Mystery**" tile.
2. In the menu on the right, select **Set 2** Blocks.
3. Move blocks onto the scale (which is already set to zero for you) and determine the mass (place the block to center of balance). Record the mass using all digits provided by the scale.
4. Then one at a time, move them into the tank of water. Make sure the block is completely submerged and not floating to get the volume of the whole block. Record the volume of the water before and after adding the block. Use all the digits provided in the simulation. (Make sure you remove each block before measuring the next one.) Subtract to determine the volume of the block itself.
5. Calculate the density of the five blocks. Collect your data in the table below. (If you get 1 g/mL for the blocks, you probably did not submerge the block. Try again.)
6. Finally, select the "Density Table" tab in the simulator. Identify the material that makes up the blocks.

	Orange Block	Brown Block	Green Block	Pink Block	Purple Block
Mass of block in kg	18.00kg	10.80kg	2.70kg	18kg	44.8kg
Volume of water in tank before block is added	100.00L	100.00L	100.00L	100.00L	100.00L
Volume of water in tank after block is submerged.	101.59L	104.00L	101.00L	104.00L	105.00L
Calculated Volume of block. (Show subtraction for first block. Keep same number of significant figures as measured volumes.)	1.59L	4L	1L	4L	5L
Calculated Density of block. (Show the calculation for the first block; Show the density formula, plug in the numbers with units, provide units on your final density.)	11.3 kg/L 11.3 g/mL	2.70g/mL	2.70 g/mL	4.50 g/mL	8.96 g/mL
Does the block float or sink?	Sink	Sink	Sink	Sink	Sink
Identity of block	Lead	Glass	Glass	Titanium	Copper

Data Analysis: Consider all your data, what makes a block sink or float? Explain

Whether or not the density of the block is less than, equal to, or greater than the density of water, 1 g/mL. If it is greater, it sinks. If it is less than or equal to, it floats.

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Module 1; Density of Liquids

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Introduction and Pre-Lab Exercises

Multiple trials, averages, ranges, % errors

Most chemistry experiments involve some type of measurement. The reliability and reproducibility of the experiments depends on the accuracy and precision of the measurements taken. **Accuracy** is how close the results are to the actual value. **Precision** is how close the results are to each other.

In most experiments, multiple trials are run to check for precision and to improve accuracy. An **average** value of the trials is determined by adding up all the values and dividing by the number of trials. The **range** of the values is determined by subtracting the lowest value from the highest value.

Measurements are most precise when their range is the smallest; that means all the values were clustered near each other and were fairly reproducible. In addition, the more significant figures available, the more precise the measurement is.

1. Three students measured the distance across a room with meter sticks. They each did the measurement 3 times. The accepted value for the measurement is 435.0 cm. Complete the table and answer the questions below:

	Trial 1	Trial 2	Trial 3	Average (unit)	Range (unit)
Student A	448.0 cm	485.6 cm	463.4 cm	465.7 cm	37.6cm
Student B	450.5 cm	441.3 cm	446.8 cm	446.2 cm	9.2cm
Student C	422.6 cm	445.2 cm	432.7 cm	440.2cm	22.6 cm

2. Which student had the most accurate measurements? Student C
3. Which student had the most precise measurements? Student B
4. What is the uncertainty in this measurement? ± 0.1 cm
5. Using the data above, calculate the percent error for Student C, Trial #1. Round your answer off to three significant figures. The formula is provided here:

$$\text{percent error} = \left(\frac{\text{measured value} - \text{accepted value}}{\text{accepted value}}\right) \times 100$$

$$\%\ \text{error} = \left|\frac{435.0 - 422.6}{435.0}\right| \times 100 = 2.851\%$$

Procedures and Data

Use the following link to access an online simulation. I suggest you use a split screen so that you can follow directions while running the experiment.

Simulation Link: http://chemcollective.org/activities/vlab/69

TRIAL #1: 12.0 mL of Compound A-1.

1. Click on "Solutions". Then select Compound A-1 by clicking on the + sign. Your solutions will appear on your workbench. (If you don't see "solutions", click on + by stockroom first.)
2. Click on + by Stockroom. Click on "Glassware". Click on Graduated Cylinders. Then select 25 mL Graduated Cylinder by clicking on the + sign. Your graduated cylinder will appear on your workbench.
3. Click on "Tools". Then select Scale by clicking on the + sign. Your scale will appear on your workbench.
4. Do step 1 as follows to measure the mass of a graduated cylinder.
   - Drag the scale to the bottom of your window.
   - Click on Tare to ensure the scale says 0.0000g.
   - Drag the graduated cylinder to cover the scale and then release. You should now see numbers on the scale.
   - Record the mass of your empty graduated cylinder.
5. Do steps as follows to Pour Compound A-1 into your graduated cylinder to measure the volume of your liquid.
   - Drag the Erlenmeyer flask with Compound A-1 to cover the graduated cylinder.
   - You should now have a window for entering desired volume.
   - Click on precise.
   - Enter a volume of 12.0 mL.
   - Click on pour.
   - Look at the bottom of the meniscus. It looks like it is right on the 12 mark, so you can use a zero for the estimated digit. Record the volume as 12.0 mL. (Note: the simulation tells you that 12.00 mL is transferred, but your graduated cylinder does not confirm that; it is only precise enough to show 12.0 mL.)
6. Determine the Mass of your Liquid.
   - After you poured 12.0 mL into your graduated cylinder, the mass should have gone up. Record that mass.
   - Now you can calculate the mass of the liquid by doing a subtraction.
7. Finally, calculate the density of the Liquid. Use the density formula, D = M/V.

TRIAL #2: 18.5 mL of Compound A-1.

1. Right-click on "workbench 1" and then select "clear workbench".
2. For Trial #2, move Compound A-1, a 25 mL graduated cylinder and a scale to your workbench as you did above.
3. Weigh the empty 25-mL Graduated cylinder as above.
4. This time put 18.5 ml of Compound A-1 into your graduated cylinder. Notice that the bottom of the meniscus is between the 18 mark and the 19 mark. If it looks halfway between, your estimated digit would be a 5. Record the value as 18.5 mL.
5. Record the mass of the graduated cylinder with Compound A-1.
6. Calculate density.

TRIAL #3: 42.8 mL of Compound A-1

For this trial, use 42.8 mL of Compound A. You will need to select a 50 mL graduated cylinder to do this. Notice that the meniscus for 42.8 mL sits right below the 43 mL mark.

Density of Liquids Data Table (Don't forget to include units on all numbers in data and calculations.)

		Trial 1:	Trial 2:	Trial 3:
Mass of empty graduated cylinder	Make sure to record all the numbers the scale provides, even the zeroes.	41.6699 g	40.4117 g	72.5619 g
Volume of liquid	Read from cylinder. Don't forget to include ONE estimated digit between the dashes. .	12.0 mL	18.5 mL	42.8 mL
Mass of graduated cylinder and liquid	The mass here should be higher than the mass of the empty graduated cylinder.	56.7899 g	63.7217 g	126.4899 g
	Show calculations below for trial 1 only.			
Mass of liquid	This is a calculation. Show the subtraction for trial #1. Keep sig.figs. to the same decimal place as the scale provided.	15.12 g	23.31 g	53.928 g
Density	Show the formula D=M/V. Plug in the numbers with units. Solve. Round off to three sig.figs (like your volume measurements).	1.26 g/mL	1.26 g/mL	1.26 g/mL

1. Compare the density you found for 12.0 mL, 18.5 mL and 42.8 mL of the liquid. How do they compare? Why?

   They are all the same despite changes to volume.

2. Calculate the average density of your three trials. Show your calculation,

   $\frac{1.26 + 1.26 + 1.26}{3} = 1.26\ g/mL$.

3. The unknown liquid was glycerol with a density of 1.25 g/mL. Which of your trials was closest to that value?

   All of them? The same density was recorded in all three trials.

4. Consider your average. What is your percent error? (The formula is in the introduction. Show your calculations). Are you analyzing accuracy or precision?

   $\% \text{ error} = \left|\frac{1.25 - 1.26}{1.25}\right| \cdot 100 = 0.8\%$ → Analyzes accuracy, not precision.

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Measurement Lab: Data Table

Use the images on pages 6-10 to complete the table below:
When you record the measurement, remember to include:

1) The estimated digit between the dashes.
2) The units.

The following seven-minute video further explains how to make measurements with an estimated digit. https://youtu.be/-Ue-o_txQAw

Figure	Measuring Device - Property	Record the measurement here.	Uncertainty	Number of significant figures
A	Ruler- Length	9.50 cm	.01 cm	3
B		5.10cm	.01cm	3
C		41.64cm	.01cm	4
D	Graduated cylinder - Volume	52.7mL	.1 cm	3
E		36.2mL	.1cm	3
F		17.5mL	.1cm	3
G	Beaker - Volume	590 mL	10 mL	2
H		46mL	1 mL	2
I	Thermometer – Temperature	31.2°C	.1°C	3
J		0.53°C	.01°C	2
K	Pressure Gauge- Pressure	37.5psi	.1 psi	3
L		0.279	.001atm	3

After you complete this table, submit it for grading. Then go to page 10 for the CHEM 101 connection.