Density Lab Test

2020-21 Division B Captain's Summer Exchange

Instructions:

- Each team has 50 minutes to complete this test.
- You may bring one binder of any size, two stand-alone calculators, and writing utensils. You are also allowed to write on this test packet.
- Only answers recorded on the answer sheet will be scored. Any answers recorded on this test packet will not be graded.
- Taking apart this test packet is permitted, but it is kindly asked of you that you put the test packet back together in the correct order.
- Scrap paper will be provided as needed.
- Tiebreakers are labeled as **(Tiebreaker)**.
- Use 9.81 m/s^2 for acceleration due to gravity.
- Appropriate significant figures are **required** in your answer. If they are not included in your final answer, the question will be marked as wrong. Credit may be given for any problems that are close to the actual answer.
- When time is up, stop writing. Failure to do so will result in a penalty or disqualification.
- Good luck and don't forget to have fun!

Section 1 – Density, Pressure and Buoyancy

1. What is density? What are some units of density? What are some types of density? Credit will be given based off of the quality of your answer. [1 point]

2. In what way are density and buoyancy related to one another? Explain how these two things affect our daily lives. [1 point]

3. 50 random people from a work building with the dimensions 80.0 meters by 40.0 meters by 50.0 meters were surveyed and were asked what their favorite color was. 23 answered red, 12 answered yellow, 3 answered green, 4 answered blue, and 18 answered purple. [6 points]

    a. What is the number density of the number of people who answered red in people/μm^3?
    b. If each of the answers to the survey were represented by marbles with a mass of 1.5 g and poured into a 100. mL container with a mass of 0.50 g, then what would be the density of the container full of marbles in g/L?
    c. Ten more people were then surveyed with this same question, and six answered red, while four answered blue. By what factor has the number density of people who answered red changed?

4. 50. grams of calcium sulfate are added to 300. mL of water. Calcium sulfate has a density of 2.32 g/mL. Calcium sulfate is insoluble in water, while sodium chloride is soluble. [10 points]

    a. What is the density of the mixture in kg/dm^3?
    b. A sphere has a radius of 0.0055 meters and its volume is 30.0% by volume oxygen gas ($\rho = 1.41$ g/L), 50.0% by volume nitrogen gas ($\rho = 1.23$ g/L), and 20.0% by volume argon gas ($\rho = 1.76$ g/L). Calculate the density and mass of the sphere. [4 points]
    c. What is the magnitude and direction of the buoyant force on the sphere if it were supposedly placed into this mixture?
    d. 55 grams of sodium chloride is then added to the mixture. The density of sodium chloride is 2.16 g/cm^3. What is the new density of the mixture?

5. Derek is trying to build a miniature version of an Egyptian Pyramid. The square base of the pyramid has a side length of 5.00 cm and the height of the pyramid is 20.0 cm. [4 points]

    a. What is the volume of this miniature pyramid in cubic nanometers?
    b. The weight of the pyramid is 15.5 N. Identify the density of the pyramid in kg/m^3, and whether or not the pyramid could float in distilled water.

6. Explain how temperature, pressure, mass, volume each affect density. Determine whether each of these factors are intensive or extensive properties of matter and answer the following question: Do extensive properties of matter affect intensive properties of matter? [4 points]

7. John is using a bow and arrows for target practice. The arrows he uses have a circular tip which each have a diameter of 1.00×10^{-3} mm. Each arrow has a mass of 2.00 grams. The target has a 40.0 cm diameter, and the bullseye in the middle has a diameter of 5.00 cm. Out of 20 attempts, John hits the bullseye 7 times, he hits anywhere on the target but the bullseye 11 times, and misses the target twice. [4 points]

    a. What is the total pressure exerted on the bullseye of the target by the arrows hit?
    b. If John shoots his arrows on a different sized target, how might the pressure exert by each of the arrows on the target change?

8. The New Year's Eve Crystal Ball has a diameter of 12.0 feet and weighs 11,875 pounds. [6 points]

a. Using US to metric unit conversions, calculate the density of the ball in g/ML.
b. Determine whether or not the ball could float in liquid gold.
c. If the ball was dropped into grape juice ($\rho = 1.07$ g/cm^3), what would be the mass value of the buoyant force on the ball in grams?

9. Peter weighs 400. N and is floating in the ocean with 5.50% of his body above water. His lungs are full of air. What is the average density of Peter in this scenario? [2 points]

10. A 6.00 cm by 15.0 cm rectangular sheet of wrapping paper has a mass of 5.0×10^{-5} g and is used to wrap a cubic-shaped gift box with a side length of 4.00 cm. The cubic box itself is of negligible mass, but the inside of the box is filled with a plastic toy with a mass of 35 grams and a volume of 30. cm^3, and the rest of the volume inside the box is filled with air, which has a density of about 1.225 kg/m^3. [10 points]

    a. Calculate the area density of the wrapping paper in μg/mm^2.
    b. If the density of the wrapping paper is 6.5 g/m^3, what is the thickness of the wrapping paper in mm?
    c. What is the density of the cubic gift box with the toy inside?
    d. Using the box from part (c), calculate the tension force and pressure exerted on the box by the fluid in the tank (assuming 50 kPa at the top of the tank) if the box is attached to the bottom of a tank full of H_2O_2 with a height of 6.0 meters by a string with a length of 0.50 meters. [4 points] **(Tiebreaker)**

11. A block has a mass of 4.50×10^4 mg. In 9.1204 sec^2, the block moves to the bottom of a 50.0-meter tank full of ethanol. [6 points]

    a. Calculate the volume of the metal block.
    b. Using the volume from part (b) and metric to US unit conversions to calculate the density of the block in pounds/m^3.
    c. Consider a homogeneous solution in which the solvent has a mass of 50 grams and a volume of 5.5×10^{-3} mm^3 and a solute which has a mass of 3.2 grams and a density of 5.1 g/cm^3. If the block was dropped into a 20.0-meter tank of this solution, how long would it take for the block to reach ½ of the way down to the bottom?

12. Ammonia solution is an aqueous solution of ammonia. Liquid ammonia has a density of 683 kg/m^3, while ammonia solution has a density of 880. kg/m^3. [4 points]

    a. What is the mass of water in grams that needs to be added to 1.00 m^3 of ammonia in order to make ammonia solution?
    b. How much mass (assuming it doesn't add volume) needs to be added to ammonia solution in order for a metal block made of silver to float?

13. A substance in the shape of a rectangular prism has dimensions of 2a (m), 4a (m), and 1.5a (cm). Its density is found to be 3.5 kg/m^3. When the rectangular block is dropped into a tub full of mystery fluid, it displaces 5.0 g of the mystery fluid and exerts a normal force of 0.5 kg at the bottom of the tub. [4 points]

    a. Identify the density of the mystery fluid in t/m^3.
    b. Calculate the value of a.

14. A steel boat has a base of 5.0 m × 2.0 m, and a height of 4.0 m. The inside of the boat is hollow and is only filled with air, which has a density of about 1.225 kg/m^3, as mentioned in an earlier problem. The boat itself is of negligible mass. What is the density of the boat in kg/m^3? [1 point]

15. A figurine composes of seven parts, a sphere, a cone, three rectangular prisms, and two cubes connected together. The sphere has a diameter of 4 cm, the cone has a diameter of 4 cm and a height of 4 cm, the rectangular prisms each have dimensions of 2 cm x 2 cm x 4 cm, and the cubes have a side length of 0.05 m. [4 points]

    a. What is the total volume of the figure in m^3?
    b. The figurine is found to sink in water. What are some possible ways to make the figurine float in water? List at least two possible ways.

Section 2 – Liquids and Gases

16. How do liquids differentiate from gases? How do liquids interact with other substances? Through different phases of matter, does a substance heated from a solid to a liquid indicate that this is a new substance? Name some liquids greater than that of the density of distilled water. [2 points]

17. Gas molecules have attractive forces within them to keep the gas molecule more attracted together. What are these attractive forces called? As the kinetic energy of a gas rises, how do you think the attractive forces between different gas molecules change? How do you think that this generally affects the way gases behave? [2 points]

18. *Choose one of the answers for each pair of words in the question below.* [1 point]

    Gas molecules with (smaller/larger) size and (higher/lower) electronegativity have higher forces of attraction with one another.

19. *Choose one of the answers in each pair of words in the question below.* [1 point]

    (Lighter/Heavier) molecules travel at faster speeds. Therefore, according to Graham's Law, the rate of effusion of gas molecules is (directly/inversely) proportional to square root of their masses.

20. Ammonia is combined with chlorine to make ammonium chloride gas. Ammonium chloride has a chemical formula of NH_4Cl. Calculate the density of this gas in g/mL at STP, using the IUPAC definition. Round your answer to 3 significant figures. [4 points]

21. Nitrogen gas makes up about 78.084% of dry air in our atmosphere. At atmospheric pressure and a temperature of 84 degrees Fahrenheit, what is the number of particles of nitrogen gas in a 1 L sample of dry air? Round your answer to 2 significant figures. [3 points]

22. 5.0 cylinder-shaped jars are filled with helium, nitrogen, oxygen, and carbon dioxide gas all at STP. Each gas takes up an equal amount of volume in each jar, which has a base radius of 10.0 cm and a height of 2.0 m. What would be the pressure in bar if all of the gases from the 5.0 jars were all combined into one jar at 40.0 degrees Celsius? [4 points]

23. 2,500 mg of Br_2 gas is held at a pressure of 1000. mm Hg and a temperature of 35 degrees Fahrenheit. What is the volume of the gas in cm^3? [2 points]

24. A gas retains a volume of 10. L at a temperature of 350 K and constant pressure. The temperature of the gas is then decreased by 40. K. This gas is then transferred to a rigid container with the same volume of the gas and at the same temperature as the gas in the second phase. The pressure of the gas in this new container is 5.5 bar. Assuming the gas is monoatomic, what is the number of particles of the gas in this new container? [4 points]

25. 15 g of hydrogen gas, 30. g of butane (C_4H_{10}) gas, and 50. g of propane gas are all combined together. The combination of this gas occupies a volume of 4.49 L at 21.5 degrees Celsius. What is the partial pressure of each gas in Pa? [6 points]

26. How many moles of H_2 have an equivalent mass of 8.00 moles of $AgNO_3$? [1 point]

27. The reaction between methane and oxygen gas creates carbon dioxide gas and water vapor as shown below:

    $CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (g)$

    What volume of oxygen gas is required to react with 800.0 grams of methane gas at a pressure of 5.00 atm and a temperature of 205 K in order to produce carbon dioxide gas? [4 points]

28. 2.45 moles of a mysterious gas are held at 90.0 degrees Celsius and a pressure of 2.3 atm. What is the volume of the gas in dm^3? [3 points]

29. A gas with a volume of 2.3×10^4 cm^3 is held at a temperature of 300. K and 20. atm. The gas pressure is increased by 500.0 kPa and the volume is decreased by a factor of 2.5. What is the new temperature of the gas in Celsius? [3 points]

30. 2.5 L of a 1.00 mole sample of a gas with a molar mass of 5.50 g/mol is evaporated after reaching a temperature of 338 K. Calculate the density and pressure of this gas. [3 points]

Section 3 – Concentrations

31. What is a concentration a measure of? What are examples of situations where concentrations used? What are some units for concentrations, such as molarity? List at least four examples. [2 points]

32. In order to make a saturated solution of saltwater, 40.0 grams of sodium chloride must be added to 100.0 grams of water. Find the particle/particle percent of salt in this solution. [3 points]

33. Consider a solution that is 15.0% by volume acetic acid ($\rho = 1.05$ g/cm^3) dissolved in 200. mL of solution, where the remaining volume is water. [7 points]

    a. Determine the molarity of the solution in mol/L.
    b. If 25.0 grams of acetic acid were somehow taken out of this solution, what would be the percent decrease of the molality of this solution? **(Tiebreaker)** [4 points]

34. 2.00×10^{-4} grams of silver are dissolved in 80.0 mL of gold. Determine the mass/volume percent of this solid-state solution. [1 point]

35. In the diagram to the right, each of the dots represent a sphere of the solute completely dissolved in this solution. Each sphere has a diameter of 3.50 cm and has a density that is 75.5% larger than the density of the solvent, which has a mass of 2,570 kg. Calculate the concentration of the solute in ppm, and determine whether or not this concentration is larger than the concentration of salt in the ocean, where the concentration of salt is about 3.5 g/L. For this question, significant figures may be ignored. [6 points] **(Tiebreaker)**