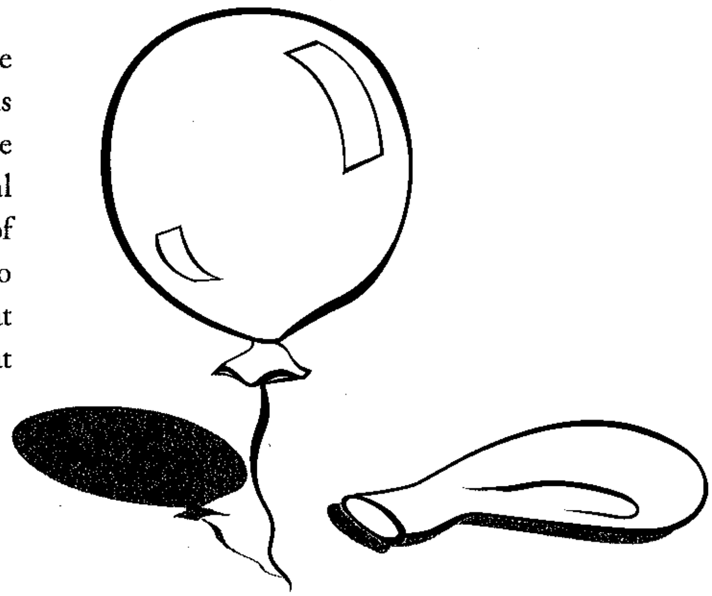
Floating Balloon



Shemal has an uninflated balloon. He fills the uninflated balloon with a gas and ties it closed. When he lets go, the balloon floats up into the sky. Shemal wonders what happens to the mass of the uninflated balloon compared to the inflated, floating balloon. What do you think? Circle the answer that best matches your thinking.

The floating balloon has more mass.

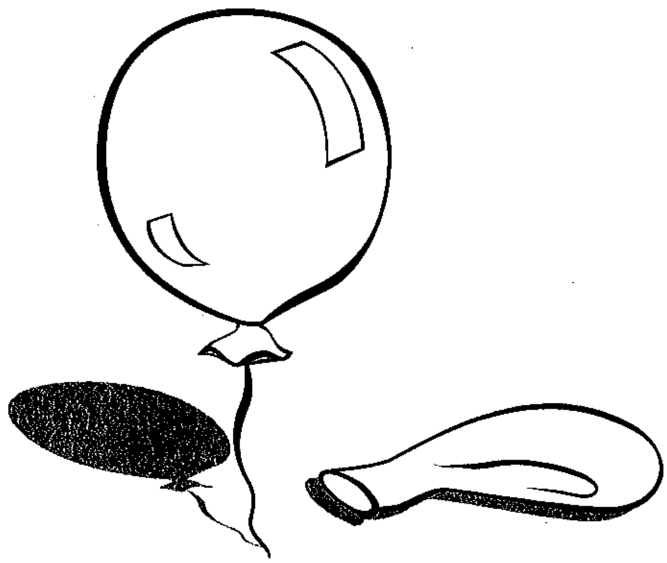
The floating balloon has less mass.

The mass of the uninflated balloon and the floating balloon is the same.

Describe your thinking. Provide an explanation for your answer.

Floating Balloon

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about the mass of a gas. The probe is designed to reveal whether students recognize that an uninflated balloon will increase in mass when inflated with a gas, even though the balloon intuitively seems lighter when it floats in the air.

Related Concepts

density, gas, kinetic molecular theory, mass, properties of matter, weight

Explanation

The best response is A: The floating balloon has a mass greater than the mass of the uninflated balloon. Gases are a form of matter and thus have mass (or weight) and take up space. Putting a gas (such as helium in this case) in a balloon adds mass, even though some students intuitively think the balloon may now be lighter because it floats. Balloons filled with helium rise because they are less dense (the total mass-to-volume ratio) than the surrounding air and not because they have a lesser mass than an uninflated balloon. Students tend to confuse density with mass. In this case, the mass of the gas-filled balloon has increased while its density has decreased with the increase in volume. A balloon filled with helium has a lesser mass (and weighs less) than a balloon blown up to the same size with air because it is less dense. However, this problem is not about comparing density, but rather comparing mass. The balloon filled with helium has a greater mass than the uninflated balloon because additional mass (matter in the form of a gas) was added to the "empty" balloon.

Curricular and Instructional Considerations

Elementary Students

At the elementary school level, students describe the properties of materials or objects and classify them as solids, liquids, or gases. Their experiences with solids and liquids are based on matter they can see. Gases are more difficult for them to understand as they have not yet developed a particulate notion of matter. However, before students proceed to middle school, it is important for elementary school students to understand that gases are matter and that they have weight (and mass).

Middle School Students

At the middle school level, students transition from focusing on the macroscopic properties of solids, liquids, and gases to explaining states of matter in terms of the position, arrangement, and motions of the atoms or molecules. Compared with students in elementary school grades, middle school students have more experience investigating gases. At this level, they should understand the idea that gases are made of molecules that have mass (and weight). As they investigate density, they discover that some gasses, like helium, are less dense than the surrounding air. However, they need to be able to distinguish between density and mass in order to reason why an object's mass (not a substance's mass) can increase while its density decreases. At this level, students begin to use the number of atoms and molecules to explain the conservation of matter or change in mass. If the number of atoms or molecules in an object remains the same before and after a change, then the mass stays the same. Conversely, if additional molecules or atoms are added to an object, such as putting gas into an "empty" balloon, then the mass increases.

High School Students

At the high school level, students deepen their understanding of gases by learning about the gas laws and behavior of fluids. However, they tend to hold on to their earlier ideas about the mass (and weight) of a gas if they are not confronted with their preconceptions. They may confuse density-related ideas with the comparison of masses (empty vs. gas-filled balloon) by not accounting for the change in volume in this phenomenon.

Administering the Probe

Students should be familiar with the rising of a helium-filled balloon. If not, consider bringing in a helium-filled balloon and an empty balloon of the same size and shape and ask students to think about the mass of each. If using this probe with younger elementary students, consider using the words *empty* instead of *uninflated* and *weight* instead of *mass* so that students' unfamiliarity with the concept of mass does not interfere with their ability to answer this question and explain their reasoning.

Related Ideas in *National Science Education Standards* (NRC 1996)

K–4 Properties of Objects and Materials

- Objects have many observable properties, including size, weight, shape, color, temperature, and the ability to react with other substances. Those properties can be measured using tools, such as rulers, balances, and thermometers.
- Materials can exist in different states, as a solid, liquid, or gas.

9–12 Structure and Properties of Matter

- Matter is made of minute particles called *atoms,* and atoms are composed of even smaller components. These components have measurable properties, such as mass.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 1993)

K–2 Structure of Matter

- Objects can be described in terms of the materials they are made of (clay, cloth, paper, etc.) and their physical properties (color, size, shape, weight, texture, flexibility, etc.).

3–5 Structure of Matter

- Materials may be composed of parts that are too small to be seen without magnification.

3–5 The Earth

- Air is a substance that surrounds us, takes up space, and whose movement we feel as wind.

6–8 Structure of Matter

- Equal volumes of different substances usually have different weights.
- The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same. (Conversely, if the number of atoms changes, then the object's mass changes.)

9–12 Structure of Matter

- An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules.

Related Research

- Students may believe that matter does not include gases or that gases are weightless materials (AAAS 1993).
- Researchers have suggested that one of the reasons students fail to recognize gases as having weight or mass is because one of their most common experiences with gases is with those that tend to rise or float (such as the helium). This view is supported by studies that show that children ages 9–13 tend to predict that gases have negative weight, such that when a gas like helium is added to a balloon, it will weigh less. Students believe that the

more gas that is added to a container, the lighter the container becomes (Driver et al. 1994).

- Students at the end of elementary school and beginning of middle school may be at different points in their conceptualization of a "theory" of matter. Although some third graders may start seeing weight as a fundamental property of all matter, many students in sixth and seventh grade still appear to think of weight simply as "felt weight"—something whose weight they cannot feel is considered to have no weight at all (AAAS 1993, p. 336).
- Many researchers have noted that students do not initially seem to be aware that air and other gases are a type of "material" and thus have properties, such as weight or mass, like other materials (Driver et al. 1994).
- The idea that air or gas has mass is not obvious to children. Yet, when it is taught, it is a concept children can acquire easily and remember (Sere 1985).
- Gases pose special difficulties for children since the ones they commonly experience, like air and helium, are invisible. It is suggested that this invisibility prevents students from developing a scientific conception of a gas. Explicit instruction is needed for children to understand the properties of a gas, including properties like mass and weight. This is in contrast to solids and liquids where students tend to learn about them intuitively (Kind 2004).

Suggestions for Instruction and Assessment

- Before students can describe the properties of a gas, they must first accept a gas as being a substance or matter.
- Provide opportunities for students to use fundamental physical dimensions such as quantity, mass, volume, pressure, and temperature to describe the state of a gas (Sere 1985).
- Provide students with opportunities to enclose a gas (such as blowing up a balloon with air) and find the mass. Compare the mass of the empty balloon with the mass of the balloon filled with air. This can also be demonstrated by balancing two empty balloons on the end of a balanced meterstick or other lever. Blow up one balloon and reattach it to show the gain in mass.
- Use particle drawings to help students reason what happens when the uninflated balloon is filled with air. Have students draw particles of air in the "empty" balloon and then draw particles of air put into the balloon and tied off so the air does not escape. Have them compare the number of particles and then ask if an increase in the number of air particles increases the mass. Once students agree that the mass increases because air particles were added and each particle adds mass, then ask what would happen if other gases were used. Establishing the idea that all gases add particles, which add mass, may lead to helping students understand why a balloon's total mass does not decrease when helium is added.

- For older students who have developed a concept of density, challenge them to show how the mass of an object containing a gas can increase while its density decreases. Have them connect this idea to the phenomenon described in the probe.

Related NSTA Science Store Publications and NSTA Journal Articles

Adams, B. 2006. Science shorts: All that matters. *Science and Children* (Sept.): 53–55.

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Related Curriculum Topic Study Guide

(Keeley 2005)

"Behavior and Characteristics of Gases"

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