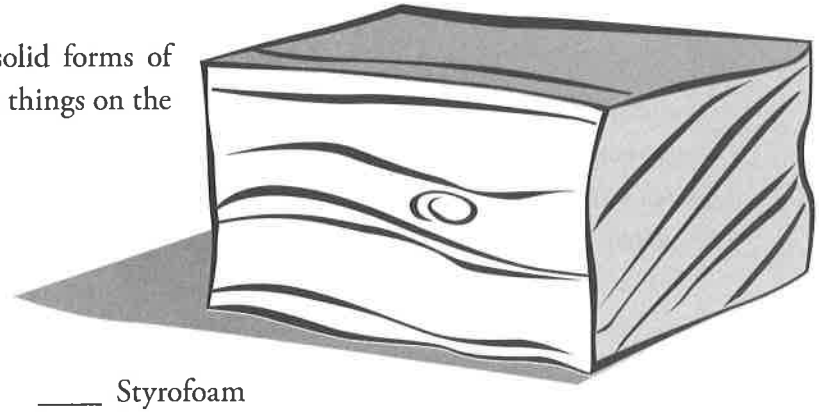
Is It a Solid?

What types of things are solid forms of matter? Put an X next to the things on the list that are solids.

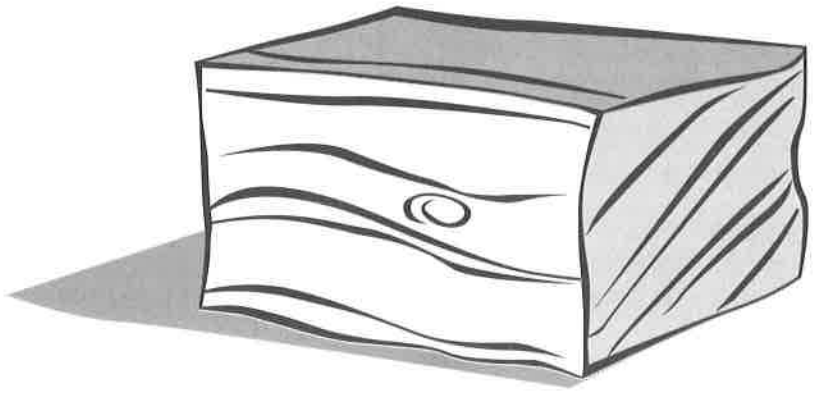


____ rock		
____ rubber band	____ Styrofoam	
____ milk	____ air	____ ice
____ feather	____ flour	____ wood
____ cloth	____ dust	____ soil
____ baby powder	____ cooking oil	____ melting wax
____ sugar	____ sponge	____ salt
____ foam-rubber ball	____ iron nail	____ cotton ball

Explain your thinking. What definition, rule, or reasoning did you use to decide whether something is a solid?

Is It a Solid?

Teacher Notes



Purpose

The purpose of this assessment probe is to elicit students' ideas about solids. The probe is designed to reveal the macroscopic and/or microscopic properties students use to decide whether a material is a solid.

Related Concepts

liquid, properties of matter, solid

Explanation

The best responses are rock, rubber band, Styrofoam, ice, feather, flour, wood, cloth, dust, soil, baby powder, sugar, sponge, salt, foam rubber ball, iron nail, and cotton ball. The items on the list that are liquids are milk, cooking oil, and melting wax. The only gas on the list is air. A solid is a material in which the atoms or molecules are in a fixed position and can only vibrate in place. The atoms or molecules in a liquid are more loosely connected; they are able to slide past one another but are not independent of each other as in a gas. However, there are some solids such as graphite (a form of carbon) that have the useful property of having layers of carbon slide over each other. Sometimes the atoms or molecules of a liquid gain enough energy to form a gas and move independently of each other. Gases have a random atomic or molecular organization and much more space between the atoms or molecules than those of a solid or liquid, which enables gases to be compressed.

From a macroscopic level, solids generally maintain their shape and have a definite

volume. Individual particles do not slide over each other, as in a liquid, which accounts for why liquids can assume the shape of their container and can be poured. Some collections of tiny parts of solid materials, such as matter in granular or powder form (sand or flour), assume the shape of their container and can be poured. However, this is because each granule or speck of powder is an individual, tiny piece of solid and not because the atoms or molecules that make up the substance are sliding over each other. It is the collection of these tiny pieces that behaves in this way, much like filling or pouring a jar full of solid marbles.

The word *solid* is often used in an everyday sense to imply something hard or not "airy." The rubber band, Styrofoam, foam-rubber ball, sponge, and cotton ball are soft or airy but they still fit the definition of a solid as a material in which the molecules are in a fixed position and vibrate in place, regardless of how hard, soft, compact, or airy the object is. However, foams may be considered neither solid nor liquid if one recognizes they are mixtures where a gas is finely dispersed within a solid.

Curricular and Instructional Considerations

Elementary Students

At the elementary level, students describe the properties of materials or objects and classify them as solids, liquids, or gases. Their definition of a solid is based on macroscopic properties such as an object keeping its shape and having a definite volume. The students' macroscopic definition of a liquid is based on the object taking the shape of its container and having a definite volume.

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 and arrangement of the atoms or molecules.

High School Students

At the high school level, students deepen their understanding of the behavior of solids, liquids, and gases based on the objects' position, arrangement, and motion. They also explore the characteristics of the fourth state of matter, plasma. They examine non-Newtonian fluids and other unusual materials, such as putties, pastes, dough, foams, and gels, including colloidal mixtures in which solid particles are mixed with water, and explain their behavior at a particle level to determine whether they are considered solids or liquids or mixtures of two different states of matter.

Administering the Probe

Eliminate objects from the list that students are not familiar with. Consider providing a visual prop, either a picture or an actual object, for each item on the list. For example, if students do not know what a foam-rubber ball is, you might show them a familiar Nerf ball toy. This probe can also be administered as a card-sort activity (Keeley 2008).

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

K–4 Properties of Objects and Materials

☆ Materials can exist in different states, as a solid, liquid, or gas.

9–12 Structure and Properties of Matter

☆ Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together. In solids, the structure is nearly rigid; in liquids, molecules or atoms move around each other but do not move apart; and in gases, molecules or atoms move almost independently of each other and are mostly far apart.

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

- Heating and cooling causes changes in the properties of materials.

6–8 Structure of Matter

☆ Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules have higher energy, are more loosely connected, and can slide past one another; some molecules may get enough energy to escape into a gas. In gases, the atoms or molecules have still more energy and are free of one another, except during occasional collisions.

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 of all ages show a wide range of beliefs about the nature and behavior of particles, including a difficulty in appreciating the intrinsic motion of particles in solids, liquids, and gases (AAAS 1993).
- A study of children's ideas about solids conducted with Israeli children ages 5–13 showed that younger children tend to associate solids with rigid materials (Stavy and Stachel 1984). They regard powders as liquids, and any nonrigid materials, such as a sponge or a cloth, as being somewhere in between a solid and liquid (Driver et al. 1994).

☆ Indicates a strong match between the ideas elicited by the probe and a national standard's learning goal.

- Students' explanation of powders as liquids is often "because they can be poured." Reasons for nonrigid objects as being neither solid nor liquid is because they "are soft," "crumble," or "can be torn." Thus children characterize the state of matter of a material according to its macroscopic appearance and behavior with the result that solids are associated with hardness, strength, and an inability to bend (Driver et al. 1994).
- By age 11, students tend to regard a powder as being an intermediate state, rather than a liquid (Driver et al. 1994).
- Stavy and Stachel (1984) concluded that children can classify liquids more easily than they can solids, perhaps because liquids are less varied in their physical characteristics (Kind 2004).
- Although some students can depict the orderly arrangement of atoms or molecules in a solid, they have difficulty recognizing the vibration of the particles (Driver et al. 1994).
- Students tend to recognize materials like metals and wood as being solids. However, students have difficulty categorizing materials that are not hard or rigid as solids. Fifty percent of 12- to 13-year-olds classified nonrigid solids like dough, sponge, sand, and sugar differently from coins, glass, or chalk. They suggest that "the easier it is to change the shape or state of the solid, the less likely it is to be included in the group of solids" (Kind 2004, p. 6).
- Children's naive view of particulate matter is based on a "seeing is believing" principle in which they tend to use sensory reasoning. Being able to accommodate a scientific particle model involves overcoming cognitive difficulties of both a conceptual and perceptual nature (Kind 2004).

Suggestions for Instruction and Assessment

- Be aware that you may have to probe deeper than just asking students to describe solids. For elementary school students, solids are just the step into the door of states of matter. Focusing instruction on just solids is not getting into the more conceptual knowledge of the states of matter.
- When investigating solids, elementary school students should be exposed to a wide variety of solids, including rigid and soft materials, porous and nonporous materials, and solids made up of small particles, such as sand and sugar.
- With elementary school students, it is important not to overemphasize ease of flow as a property of liquids, since solids such as sand and salt seem to have this property. Instead, concentrate on the individual particles with a hand lens and pencil point, observing that each grain has its own form and keeps that form when pushed or squashed, unlike a drop of water. Have students observe how the solid particles form a heap when poured out onto a flat surface, which liquids do not. By beginning with coarse particles such as sand or salt, children can go on to see that finer powders like flour and baby powder are also solids (Wenham 2005).
- Students should also observe and describe

the behavior of collections of larger pieces, such as marbles, sugar cubes, or wooden blocks (which can, for example, be poured out of a container), and consider that the collections may have new properties that the individual pieces do not (AAAS 1993, p. 76). Relate this to smaller pieces in materials like powders, sand, salt, and sugar.

- Researchers suggest that upper elementary school students (around age 11) have an opportunity to develop the idea that a powder is composed of small pieces of a solid. However, researchers warn that, when subsequently learning the particulate theory of solids, students may wrongly infer that the theoretical particles are "powder grains." Therefore, it is suggested that, before they learn particulate theory, students should be capable of classifying materials according to a scientific view of the states of matter (Driver et al. 1994, p. 79).
- It is important to develop the concept of particulate solids before investigating colloids and suspensions.

Related NSTA Science Store Publications and NSTA Journal Articles

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

American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

Buchanan, K. 2005. Idea bank: Oobleck and beyond. *The Science Teacher* (Dec.): 52–54.

Driver, R., A. Squires, P. Rushworth, and V. Wood-Robinson. 1994. *Making sense of secondary science: Research into children's ideas.* London and New York: RoutledgeFalmer.

Keeley, P. 2005. *Science curriculum topic study: Bridging the gap between standards and practice.* Thousand Oaks, CA: Corwin Press.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Ontario Science Center. 1995. *Solids, liquids, and gases: Starting with science series.* Toronto: Kids Can Press.

Related Curriculum Topic Study Guides

(Keeley 2005)

"Particulate Nature of Matter" (Atoms and Molecules)

"Solids"

"States of Matter"

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American Association for the Advancement of Science (AAAS). 1993. *Benchmarks for science literacy.* New York: Oxford University Press.

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Kind, V. 2004. *Beyond appearances: Students' misconceptions about basic chemical ideas.* 2nd ed. Durham, England: Durham University School of Education. Also available online at *www.chemsoc.org/pdf/LearnNet/rsc/miscon.pdf.*

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.

Stavy, R., and Stachel, D. 1984. *Children's ideas about "solid" and "liquid."* Tel Aviv, Israel: Israeli Science Teaching Center, School of Education, Tel Aviv University.

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