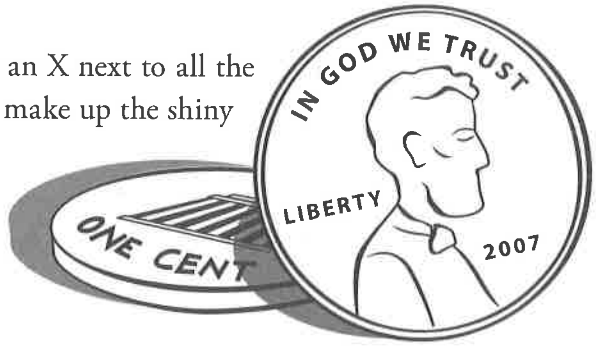
Pennies

A shiny new penny is made up of atoms. Put an X next to all the things on the list that describe the atoms that make up the shiny new penny.



___ hard

___ soft

___ solid

___ copper-colored

___ very small

___ has mass

___ always moving

___ do not move

___ cold

___ warm

___ shiny

___ dull

___ made of smaller particles

___ contains mostly empty space

Describe your thinking about the atoms that make up the penny. Explain why you selected the things on the list as ways to describe atoms.

Pennies

Teacher Notes

Purpose

The purpose of this assessment probe is to elicit students' ideas about the properties of atoms. The probe is designed to determine whether students can distinguish between the microscopic properties of an atom and the macroscopic properties of a substance or object made up of atoms.

Related Concepts

atom, properties of matter

Explanation

Five items on the list make up the best response: very small, has mass, always moving, made of smaller particles, and contains mostly empty space. Atoms are the smallest particles of matter that make up the substances zinc and copper (elements) in the penny. Most pennies circulating today are made up of 97.5% zinc and 2.5% copper. If a penny were made of pure copper, it would contain about 2.4×10^{24} copper atoms. This indicates that the size of an individual atom is very small. A penny weighs only about 2 g. With over 10^{24} atoms in a penny, this shows that the mass of an individual atom is extremely small, yet it still has mass. Atoms and molecules are always in motion and reach a minimum of motion in very extreme, cold conditions. Since the penny is a solid, the atoms that make up the penny are in a fixed position and can only move by vibrating. An atom is mostly empty space. Even though the zinc and copper atoms make up the solid substance of the penny, the atoms themselves are mostly empty space. They consist of a small, dense nucleus surrounded by electrons that move in an area of space about a trillion times larger in volume than the nucleus, making the total atom mostly empty space. The atom is made up of even smaller particles—protons and neutrons in the nucleus and electrons found outside the nucleus. Scientists have discovered even smaller particles that make up the protons and neutrons. Properties such as hard, solid, copper-colored, shiny, cold (or warm) describe the macroscopic properties of the substances (zinc and copper) or object (penny) and are not the properties of the individual atoms.

Curricular and Instructional Considerations

Elementary Students

At the elementary school level, students describe the properties of materials, objects, and familiar substances, like water. The focus is on observable and measurable properties of macroscopic matter.

Middle School Students

At the middle school level, students transition from focusing on the properties of objects and materials to the properties of substances. They develop an understanding of the atom as the smallest unit of matter that has mass and takes up space. They begin to distinguish between states of matter by using the idea of position and movement of atoms and molecules. However, the idea of empty space within an atom and between atoms is difficult for students at this age because they still tend to view matter as a continuous substance.

High School Students

At the high school level, students learn about the physical and chemical properties of atoms. They learn to distinguish between the macroscopic properties of elements and the microscopic properties of the atoms that make up elements. At this level, they learn about subatomic particles and the architecture of an atom. Their deepening understanding of kinetic molecular theory, introduced in middle school, helps them recognize that atoms and molecules are constantly moving and reach a minimum of motion in temperatures approaching absolute zero (0° Kelvin).

Administering the Probe

Because this probe targets ideas related to the properties of atoms, it is most suitable for middle school and high school grades. Consider showing students a shiny new penny and, although they do not need to know the composition of new pennies for this probe, you can explain that pennies today are not made entirely of copper.

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.

9–12 Structure of Atoms

- ☆ Matter is made of minute particles called *atoms,* and atoms are composed of even smaller components. These components have measurable properties, such as mass and electric charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons.

9–12 Structure and Properties of Matter

- Atoms interact with one another by transferring or sharing electrons that are farthest from the nucleus. These outer electrons govern the chemical properties of the element.
- 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

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

6–8 Structure of Matter

- All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.
- ☆ Atoms and molecules are perpetually in motion. In solids, the atoms are closely locked in position and can only vibrate.

9–12 Structure of Matter

- ☆ Atoms are made of a positive nucleus surrounded by negative electrons.
- ☆ The nucleus, a tiny fraction of the volume of an atom, is composed of protons and neutrons, each almost 2,000 times heavier than an electron. The number of positive protons in the nucleus determines what an atom's electron configuration can be and so defines the element.
- Scientists continue to investigate atoms and have discovered even smaller constituents of which neutrons and protons are made.

Related Research

- Middle school and high school students are deeply committed to a theory of continuous matter. Although some students may think

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

that substances can be divided up into small particles, they do not recognize the particles as building blocks, but as formed of basically continuous substances under certain conditions (AAAS 1993, p. 336).

- Students of all ages show a wide range of beliefs about the nature and behavior of particles, including a lack of appreciation of the very small size of particles (AAAS 1993).
- Some students, when recognizing the minute size of atoms, reason that because atoms are so small they have zero or negligible mass (Driver et al. 1994).
- 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).
- Several studies of students' initial conception of an atom show that they perceive it either as "a small piece of material" or the "ultimate bit of material obtained when a portion of material is progressively subdivided." Such "bits" are thought to vary in size and shape and possess properties similar to the properties of the parent material. For example, some students consider atoms of a solid to have all or most of the macro properties that they associate with the solid, such as hardness, hotness/coldness, color, and state of matter (Driver et al. 1994, p. 74).
- 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 perceptive nature (Kind 2004).

Suggestions for Instruction and Assessment

- Be explicit in developing the idea that any property of a material is a result of the arrangement of the particles, not a result of the individual particles having that property.
- Ask students to draw what they think an atom and a group of atoms look like. Their representations will vary and can be used as starting points for discussions about the properties of things we cannot see.
- Do not assume students will recognize the difference between properties of atoms and properties of substances. After teaching about properties of atoms and molecules, provide an opportunity for students to use a graphic organizer to compare and contrast microscopic and macroscopic properties at a substance and atomic/molecular level. Repeat this using an example of a solid, liquid, and gaseous substance.
- Be up-front with students about the difficulty in conceptualizing small particles like atoms and molecules. Explain how scientists have been trying to understand atoms for the last 2,000 years, and it was not until the early 19th century that the idea of atoms was accepted. It took more than a century after that to understand the structure of atoms, which is still being studied by scientists today. If it took scientists this long to understand the particulate nature of matter, then do not expect

students to change their models overnight (Kind 2004).

- Have students imagine they are wearing "atomic spectacles" that allow them to "see" atoms. Show them a shiny penny, nickel, or dime and ask them what the atoms look like. Encourage them to draw the atoms. Have them discuss the differences and similarities between their ideas and drawings, further probing for ideas about color or continuous matter.
- Use analogies to depict the very small size of atoms in relation to the total volume of an atom.
- Demonstrate how something that is non-continuous can look continuous depending on the magnitude of our view. For example, show students a sponge and have them examine the many holes. Stand far enough away so that students cannot see the individual holes. The sponge will look like a continuous block of matter, even though it is full of holes. Relate this to looking at the penny without powers of magnification that would allow one to see at the atomic level.
- Representations of atoms often lead to students' misconceptions. Use the PRISMS (Phenomena and Representations for Instruction of Science in Middle School) website at *http://prisms.mmsa.org* to find examples of atomic representations, along with their likely instructional effectiveness, that can be used in teaching about atoms.

Related NSTA Science Store Publications and NSTA Journal Articles

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

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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.

Hazen, R., and J. Trefil. 1991. *Science matters: Achieving scientific literacy.* New York: Anchor Books.

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

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

Related Curriculum Topic Study Guide

(Keeley 2005)

"Particulate Nature of Matter (Atoms and Molecules)"

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