10.2 Properties of Solids

All matter is made up of tiny atoms and molecules. In a solid, the atoms or molecules are closely packed, and they stay in place. This is why solids hold their shape. In this section, you will learn how the properties of solids are a result of the behavior of atoms and molecules.

Matter has physical and chemical properties

Characteristics of matter Different kinds of matter have different characteristics. They melt and boil at a wide range of temperatures. They might be different colors or have different odors. Some can stretch without breaking, while others shatter easily. These, and other properties, help us distinguish one substance from another. These properties also help us choose which kind of material to use for a specific purpose.

Physical properties Characteristics that can be observed directly are called **physical properties**. Physical properties include color, odor, texture, density, brittleness, and state (solid, liquid, or gas). Substances can often be identified by their physical properties. For example, water is a colorless, odorless substance that exists as a liquid at room temperature. Gold is shiny, exists as a solid at room temperature, and can be pounded into very thin sheets.

Physical changes A *physical change* is any change in the size, shape, or phase of matter in which the identity of a substance does not change. For example, when water is frozen, it changes from a liquid to a solid. This does not change the water into a new substance. It is still water, only in solid form which we call ice. The change can easily be reversed by melting the solid water. Bending a steel bar causes another example of a physical change.

Chemical properties Properties that can only be observed when a substance changes into a different substance are called **chemical properties**. For example, if you leave an iron nail outside, it will eventually rust. A chemical property of iron is that it reacts with oxygen in the air to form iron oxide (rust). Any change that transforms one substance into a different substance is called a *chemical change* (Figure 10.8). Chemical changes are not easily reversible. Rusted iron will not turn shiny again, even if you remove it from oxygen in the air.

VOCABULARY

physical properties - characteristics that can be observed directly.

chemical properties - characteristics that can only be observed when a substance changes into a different substance.

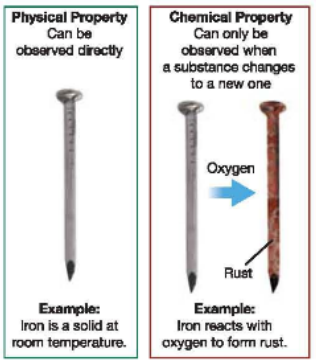


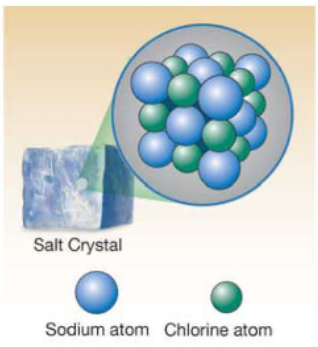
Figure 10.8: *Physical and chemical properties of iron.*

The arrangement of atoms and molecules in solids

Crystalline and amorphous solids

The atoms or molecules in a solid can be arranged in two ways. If the particles are arranged in an orderly, repeating pattern, the solid is called **crystalline**. Examples of crystalline solids include salts, minerals, and metals. If the particles are arranged in a random way, the solid is **amorphous**. Examples of amorphous solids include rubber, wax, and glass.

Crystalline solids



Most solids on Earth are crystalline. Some materials, like salt, exist as single crystals and you can see the arrangement of atoms reflected in the shape of the crystal. If you look at a crystal of table salt under a microscope, you'll see that it's cubic in shape. If you could examine the arrangement of atoms, you would see that the shape of the crystal comes from the cubic arrangement of sodium and chlorine atoms. Metals are also crystalline. They don't look like "crystals" because solid metal is made from very tiny crystals fused together in a jumble of different orientations (Figure 10.9).

Amorphous solids

The word *amorphous* comes from the Greek for "without shape." Unlike crystals, amorphous solids do not have a repetitive pattern in the arrangement of molecules or atoms. The atoms or molecules are randomly arranged. While amorphous solids also hold their shape, they are often softer and more elastic than crystalline solids. This is because a molecule in an amorphous solid is not tightly connected to as many neighboring molecules as it would be in a crystalline solid. Glass is a common amorphous solid. Glass is hard and brittle because it is made from molten silica crystals that are cooled quickly, before they have time to recrystallize. The rapid cooling leaves the silica molecules in a random arrangement. Plastic is another useful amorphous solid.

VOCABULARY

crystalline - an orderly, repeating arrangement of atoms or molecules in a solid.

amorphous - a random arrangement of atoms or molecules in a solid.

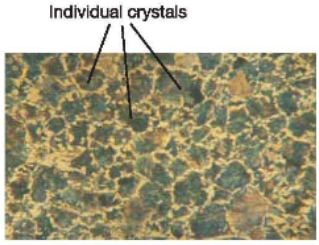
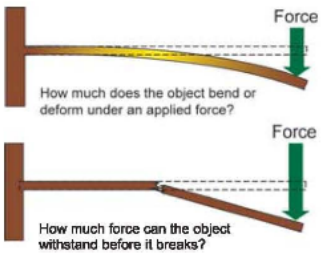


Figure 10.9: *Metallic crystals in steel. Single crystals are very small. This image was taken with an electron microscope at very high magnification.*

Mechanical properties of solids

The meaning of *strength*



When you apply a force to an object, the object might change its size, shape, or both. The concept of **strength** describes the ability of a solid object to maintain its shape even when force is applied. The strength of an object can be determined based on the answers to the two questions in the illustration to the left.

Tensile strength **Tensile strength** is a measure of how much stress from pulling, or tension, a material can withstand before breaking (Figure 10.10). Strong materials like steel have high tensile strength. Weak materials like wax and rubber have low tensile strength. Brittle materials also have low tensile strength.

Hardness **Hardness** measures a solid's resistance to scratching. Diamond is the hardest natural substance found on Earth. Geologists sometimes classify rocks based on hardness. Given six different kinds of rock, how could you line them up in order of increasing hardness?

Elasticity If you pull on a rubber band, its shape changes. If you let it go, the rubber band returns to its original shape. Rubber bands can stretch many times their original length before breaking, a property called elasticity. **Elasticity** describes a solid's ability to be stretched and then return to its original size. This property also gives objects the ability to bounce and to withstand impact without breaking.

Brittleness **Brittleness** is defined as the tendency of a solid to crack or break before stretching very much. Glass is a good example of a brittle material. You cannot stretch glass even one-tenth of a percent (0.001) before it breaks. To stretch or shape glass you need to heat the glass until it is almost melted. Heating causes molecules to move faster, temporarily breaking the forces that hold them together.

VOCABULARY

strength - the ability to maintain shape under the application of force.

tensile strength - a measure of how much stress from pulling, or tension, a material can withstand before breaking.

hardness - a measure of a solid's resistance to scratching.

elasticity - the ability to be stretched or compressed and then return to original size.

brittleness - the tendency to crack or break; the opposite of elasticity.

Tensile Strength

Figure 10.10: *Tensile strength measures how much pulling, or tension, a material can withstand before breaking.*

Ductility One of the most useful properties of metals is that they are ductile. A ductile material can be bent a relatively large amount without breaking. For example, a steel fork can be bent in half and the steel will not break. A plastic fork cracks when it is bent only a small amount. Steel's high **ductility** means steel can be formed into useful shapes by pulling, rolling, and bending. These processes would destroy a brittle material like glass. The ductility of many metals, such as copper, allow them to be formed into wire like the copper wire shown below.

What is malleability? **Malleability** measures a solid's ability to be pounded into thin sheets. Aluminum is a highly malleable metal. Aluminum foil and beverage cans are two good examples of how manufacturers take advantage of the malleability of aluminum.

Thermal expansion As the temperature increases, the kinetic energy in the vibration of atoms and molecules also increases. The increased vibration makes each particle take up a little more space, causing **thermal expansion**. Almost all solid materials expand as the temperature increases. Some materials (like plastic) expand a great deal. Other materials (like glass) expand only a little. All bridges longer than a certain size have special joints that allow the bridge surface to expand and contract with changes in temperature (Figure 10.11). The bridge surface would crack without these expansion joints.

VOCABULARY

ductility - the ability to bend without breaking.

malleability - the ability of a solid to be pounded into thin sheets.

thermal expansion - the tendency of the atoms or molecules in a substance (solid, liquid, or gas) to take up more space as the temperature increases.

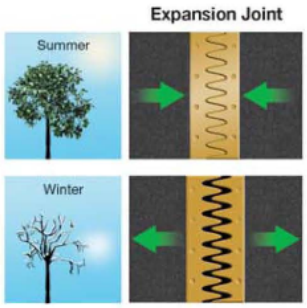


Figure 10.11: *Bridges have expansion joints to allow for thermal expansion of concrete.*

Section 10.2 Review

1. Name one example of a physical change and one example of a chemical change.
2. Name one example of a material for each set of properties.
   a. high elasticity and high tensile strength
   b. amorphous and brittle
   c. crystalline and brittle
   d. amorphous and elastic
   e. ductile and crystalline
3. The strength of a material determines
   a. how dense the material is
   b. how much force it can withstand before breaking
   c. how good a thermal or electrical conductor it is
4. Latex is a soft, stretchy, rubber-like material. Would you expect latex to be crystalline or amorphous?
5. Explain, from an atomic-level perspective, why expansion joints are used in bridges.
6. Which property of a metal describes why it can be formed into wire?
7. When installing wood floors, it is often recommended that you leave a half-inch of space between the flooring and the wall (Figure 10.12). Why do you think this space would be recommended?
8. Aluminum can be made into foil because aluminum has high ____.

STUDY SKILLS

Physical Property Flashcards

Make flash cards that will help you remember the meanings of the physical properties discussed in this section.

Write a property on one side of a card and the definition and some examples on the other side. For example, write *amorphous* on one side of a card and "random arrangement of molecules in a solid" on the other side. In addition, list some examples of amorphous solids such as glass and wax.

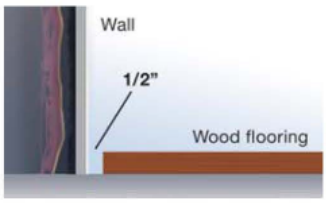


Figure 10.12: *Question 7.*