However, if you simply allow the sugar to remain at the bottom of the cup and slowly dissolve on its own, then, before spontaneous mixing has a chance to occur, the resulting mixture has different properties near the top of the liquid, where there is little dissolved sugar per gram of coffee, compared to the bottom, where it is mainly sugar. Mixtures of substances that do *not* have uniform properties throughout are called **heterogeneous mixtures.** Sometimes regions of one substance exist permanently beside regions of the other substances in such mixtures. In contrast to a homogeneous mixture, where the mixing extends right down to the atomic level, a heterogeneous mixture has zones where there is exclusively one type of substance or another (see Figure 1.7b). In many cases, you can see the heterogeneity of a mixture with your naked eye—think for example of wood with a grain, or beef in which the fat and muscle are clearly distinguishable, or rock in which separate components are obvious. Separating such complex mixtures into components that are individually uniform is known as *purifying* the substances.

It is important to fully understand the fundamental difference between compounds on the one hand and simple mixtures of substances on the other. To summarize what we have described:

Compound	Mixture
Elements are present in only one unique ratio.	Elements are present in no fixed proportion.
Combination often occurs with emission of light and/or much heat.	Usually mixing produces no dramatic evidence of change.
Fundamental change occurs at the atomic level when the compound forms.	No fundamental change occurs at the atomic level.
Properties are quite distinct from those of component elements.	Properties often are an average of those of the components.
Cannot be readily resolved back to its components by simple techniques.	Can be readily resolved into components without drastic measures.

The conceptual relationships among the various forms of matter we have discussed so far are summarized in Figure 1.8.

Exercise 1.1

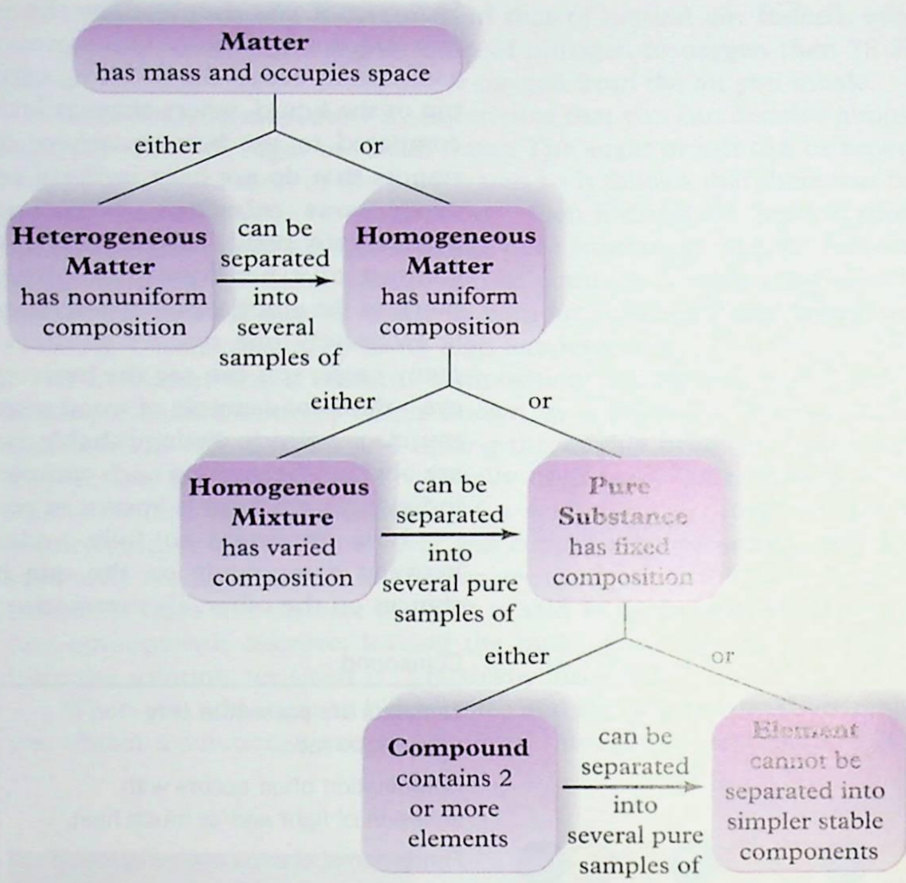
Classify each of the following materials as either a homogeneous or a heterogeneous mixture, based upon what you observe about them, and explain your answers:

a) a U.S. quarter coin **b)** freshly squeezed orange juice **c)** clear tea

1.8 Some heterogeneous mixtures look deceptively like homogeneous ones

The classification of most materials, such as water, sugar, salt, and air, as liquids, solids, or gases seems straightforward to us. But what about jelly—is it a liquid or a solid? What about a cloud—is it a gas or a liquid?

Figure 1.8 Classification scheme for the various forms of matter.



These situations, in which the substance seems to have some of the characteristic properties of two different states of matter, are found to invariably involve two (or more) different substances, present in a heterogeneous mixture. We are fooled into thinking that the mixture is a single, homogeneous substance because the particles involved are so small that we cannot distinguish them with our unaided eyes, even though they are much bigger than atoms.

Many common substances that appear uniform to the naked eye are seen under magnification to actually be heterogeneous mixtures consisting of two or more types of materials, with one finely divided material dispersed in the other. The general name for such a substance is **colloid.** An example is homogenized milk, which under an ordinary microscope can be seen to consist of individual fat particles suspended in a watery substance. *Homogenized* milk is actually a *heterogeneous* mixture. The term *homogenized* comes from the fact that the butterfat is premixed into the liquid, not separate as a layer of cream at the top.

In general, in a colloid, tiny particles of one substance, whether gas, liquid, or solid, are dispersed in the more prominent substance, whether gas, liquid, or solid. The dispersed particles in colloids have diameters in the range of 1 to 1000 nanometers (10^{-9} to 10^{-6} meters), whereas in

Table 1.2 Types of colloids

A **solid** dispersed in a	is called a(n)	Common examples
gas	aerosol	smoke, dust in air
liquid	sol	mud, paint
solid	solid sol	some alloys (e.g., steel)
A **liquid** dispersed in a	is called a(n)	Common examples
gas	aerosol	fog, clouds
liquid	emulsion	milk, mayonnaise
solid	gel	jelly, shaving preparations
A **gas** dispersed in a	is called a	Common examples
liquid	foam	whipped cream, soap suds
solid	solid foam	ice cream, Styrofoam, popcorn, marshmallows

solutions, the dissolved particles are of the size of atoms, that is, about 0.1 to 1 nm (10^{-10} to 10^{-9} meters). The substances in a colloid are not soluble in each other. They do not form a homogeneous solution and often eventually separate unless the mixture is kept agitated. The various types of colloids are listed in Table 1.2. Note that both clouds and jelly are colloids.

1.9 Emulsions are useful colloids

Colloids can be very useful and important in many areas of life. Particularly important commercially are **emulsions,** colloids in which both components are liquids. In many cases, one phase in the emulsion is water, and the other is an oily substance. Emulsions consisting of oil and water are commonly used as skin *moisturizers,* or *emollients* to give them their more scientific name. People use these products after washing—a process that removes much of the skin's own oils—to provide lubrication of the dry skin until the body gradually replenishes its natural oils. Using a pure oil, rather than an emulsion, would leave the skin feeling very greasy. The emulsion feels more natural to the skin, and it also supplies water, some of which is absorbed by the skin. A *lotion* is an emulsion of this type that feels more like a liquid, whereas a *cream* seems more like a solid.

Emulsions are also common in food products—ice cream and mayonnaise are two familiar examples. Ice cream is an emulsion of fat (cream) in a water solution containing sugar and flavorings. The two liquids in an emulsion are insoluble in each other and in many cases would spontaneously separate if a small amount of an **emulsifying agent,** a substance that is soluble in both of them and that therefore stabilizes the copresence of the two, were not present (see Figure 1.9). For example, egg yolk is used as the emulsifying agent in mayonnaise, because the egg yolk keeps water droplets evenly dispersed in the vegetable oil that is the dominant constituent.

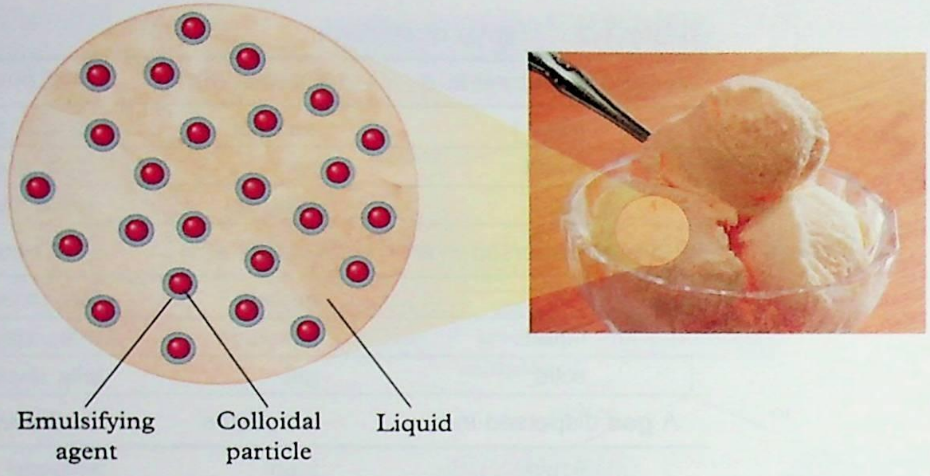


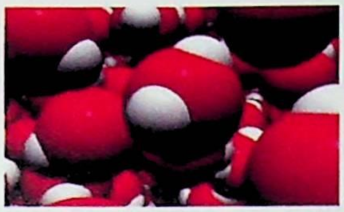
Figure 1.9 An emulsifying agent surrounds colloidal particles and helps keep them dispersed in a liquid. *(George Semple for W. H. Freeman and Company)*

Your body houses solutions and mixtures similar to the ones we have been describing. Blood, for instance, is a complex system that has characteristics of solutions, mixtures, and colloids. Water is the most prominent substance in blood and disperses compounds and biological substances such as enzymes, hormones, and cells. Your body also produces an emulsifying agent called bile that helps to keep fatty substances dispersed in watery body fluids.

Activity: Emulsification in the kitchen

Egg yolks are not the only foods that act as emulsifying agents. Onions and mustard also assist in stabilizing oil-in-water emulsifications. Follow the recipe for the vinaigrette dressing below, but omit the mustard and onion. Put all the ingredients in a small glass bowl or jar and whisk or shake the jar to mix. Let the mixture stand for two minutes. What happens to the oil and vinegar? Are they emulsified? Now add the onions and mustard and shake vigorously. Does the mixture look different? How? Let the dressing stand for two minutes. Do the oil and vinegar components separate? In this recipe there are 4 parts oil to 1 part vinegar. If you change this ratio, you can increase the time before the emulsification breaks down. Would you increase or decrease the amount of oil to increase the stability of the emulsification? Explain your choice. The recipe is:

1/4 cup olive oil (or any salad oil)
2 tablespoons red wine vinegar
1/2 teaspoon finely minced onion
1/8 teaspoon mustard
pinch salt (to taste)
pinch pepper (to taste)



View the molecular-level activity of gaseous, liquid, and solid water at Chapter 1: Visualizations: Media Link 6.

States of Matter

We know from common experience that there are three common states in which matter can exist. Your body contains matter in all three physical states: *solid, liquid, and gas* (see Figure 1.10). Bone, teeth, hair, skin, muscle, tendons, and cartilage are all solids. Blood and body fluids are liquids. Gases enter your lungs when you breathe in and leave when you exhale. You also find gases in the intestine, where they are produced as a by-product of bacterial activity; emission of these gases constitutes what we call *flatulence*.

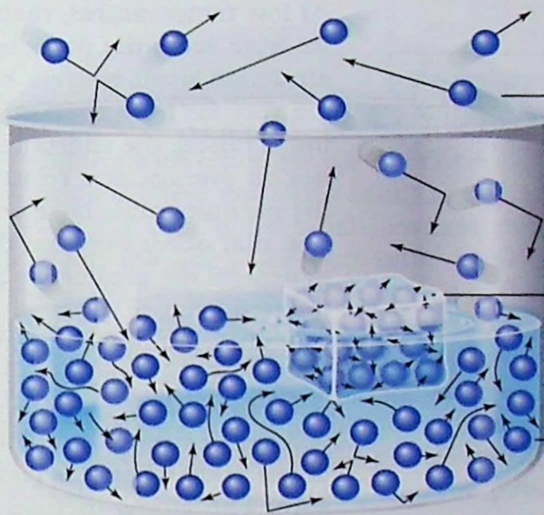


Figure 1.10 A schematic representation of the spacing and motion of the independent particles in gas, liquid, and solid states of matter.

1.10 The particles in solids and liquids are relatively close together

Evidence provided by the microscope (discussed in section 1.4) has indicated that the atoms in solid metals lie very close together. As a consequence, it is not generally possible to force the atoms any closer to each other. Indeed, we know from experience—for example, with ice cubes—that it is very difficult to compress any solid, even if we apply considerable pressure to it. The same generalization about atoms lying close together must be true for liquids, since the volume occupied by a given mass of matter in the liquid state is almost identical with that for the solid state. Liquids, too, are difficult to compress. For example, we know from experience that applying pressure to try to squeeze liquid water into a smaller volume is a futile exercise!

The particles that make up a solid are quite fixed in location and execute only small motions about their average positions, rarely "getting anywhere" as a result. In contrast, particles in a liquid do travel. We know that motion of the particles past each other must occur, since we

Fact or Fiction?

Antique windowpanes are thicker at the bottom than at the top because glass flows to the bottom over time.

Actually glass is an amorphous solid that is similar to liquids in *structure* but not in state; therefore, it does not flow. The variability in the thickness of antique windowpanes is due to the manufacturing processes used at the time, which could not produce glass of constant thickness. There are no statistical studies that indicate most antique windows are thicker at the bottom.