



Figure 1 Water pipes or connectors made of lead can be a source of lead contamination in the drinking water of older homes. The pipes connect the home plumbing system to the public water main under the street.

CAREER LINK

A water quality testing technician can work in many environments, from rural outdoor situations to inside large manufacturing facilities. To find out more about this career,



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In 2010, the Ontario city of Hamilton issued notices to many of its residents warning of possible lead contamination in their drinking water. Homes built before 1955 were particularly at risk. When these homes were constructed, tradespeople sometimes used lead pipes to link the plumbing in homes to the main water supply under the street (**Figure 1**). Long-term or chronic exposure to lead is a concern because it impairs brain and nervous system development, particularly in children.

How does lead get into the water? If you recall, lead is just above hydrogen on the activity series of metals. This means that lead in the pipes can react with the water, especially if it is slightly acidic. This reaction releases toxic lead ions into the water. The longer the water remains in contact with lead, the greater its concentration of lead ions. As a precaution, Hamilton city officials advised residents to run their taps for five minutes before using the water for drinking or cooking. However, a better way to solve the problem is to remove the source of the contamination: replace the lead pipes.

Tap water is a mixture of a variety of dissolved substances. Some minerals and gases occur naturally in water. Others are intentionally added to improve the quality of drinking water. These include chlorine for disinfection and fluoride compounds to help prevent dental decay. Municipalities conduct frequent tests to ensure that the water coming out of your tap is a clear, colourless solution that is safe to drink. 🌍

What Is a Solution?

A solution is a homogeneous mixture of two or more substances. It is a homogeneous mixture because there is only one phase and the components are uniformly mixed, giving a uniform appearance. (“Phase” means “visible part.”) As a result, samples taken from two different locations in the solution have exactly the same composition. That is why the first few millilitres of clear apple juice taste just as sweet as the last.

Solutions can be solids, liquids, or gases. Liquid and gaseous solutions are transparent because the entities they contain are too small to block light as it passes through. Solutions may be coloured or colourless depending on the substances they contain.

Let’s consider a specific solution: the glucose solution used for intravenous (IV) drips. Glucose (sometimes called dextrose) is a form of sugar. To prepare this solution, a specific mass of glucose, $C_6H_{12}O_6$, is first dissolved in water. After the glucose and water are thoroughly mixed, the grains of glucose are no longer visible (**Figure 2**). At the molecular level, the molecules within each grain have separated and are dispersed evenly throughout the flask. Each molecule is in direct contact with water molecules. Since the mass of these molecules is so small, they will never settle to the bottom of the flask. The diameter of these molecules is also extremely small (in the order of 10^{-9} m), so light can pass directly through the mixture. The result is a clear homogeneous mixture: a solution. This liquid looks just like pure water, but it is different at the molecular level.

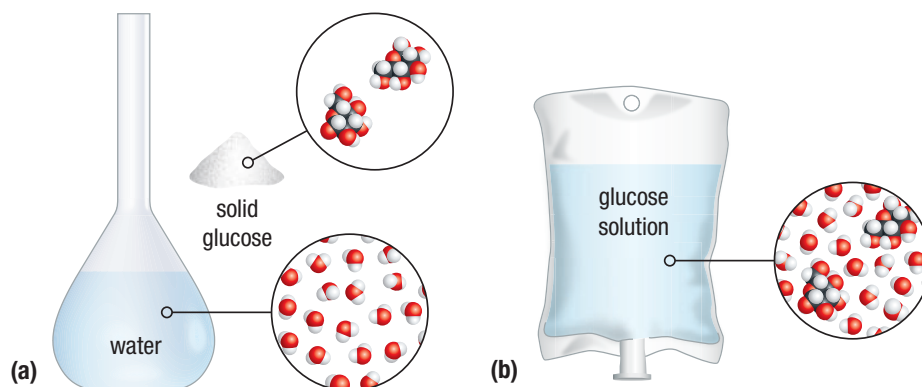


Figure 2 (a) Solid glucose and liquid water are mixed to make a glucose solution for an IV drip. (b) Glucose molecules are evenly distributed in the transparent solution.

Homogeneous and Heterogeneous Mixtures

Solutions are homogeneous mixtures because they are uniform and have only one phase. A **heterogeneous mixture** has two or more phases. Oil and vinegar is an example of a heterogeneous mixture. Even though they are both liquids, oil and vinegar (which is mostly water) separate into two distinct layers or phases. Other mixtures, such as blood and milk, at first appear to be homogeneous, but a closer look reveals that they are not. If you looked at a blood sample under the microscope you would see that it is made up of many different cells suspended in a liquid (**Figure 3**). Its composition is hardly uniform. Blood is a heterogeneous mixture. In fact, all liquid and gaseous mixtures that are translucent (semi-transparent) or opaque (not transparent) are heterogeneous mixtures.

heterogeneous mixture a mixture that contains two or more phases

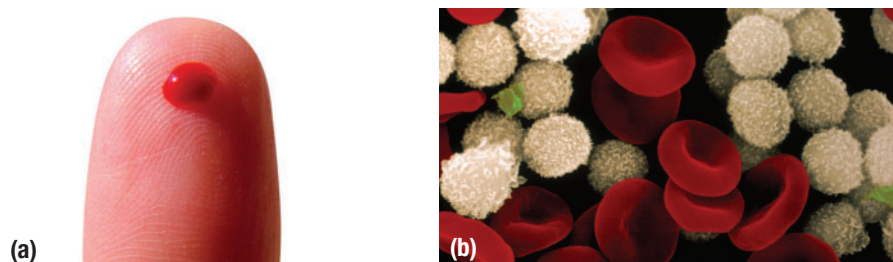


Figure 3 To the unaided eye, a blood sample appears to be homogeneous. Under the microscope, however, blood is a heterogeneous mixture of various types of cells. Blood cells are about 1000 times larger than sugar molecules—large enough to block light from passing through.

Air is an example of a mixture that, depending on its composition, can be either homogeneous or heterogeneous. Dry, clean air is a homogeneous mixture or solution of mostly nitrogen, oxygen, argon, and carbon dioxide. Air is transparent because the gas entities it contains are too small to interfere with the passage of light. The difference in entity size can sometimes be used to distinguish solutions from other mixtures that appear to be homogeneous. The air in your classroom may also appear to be homogeneous. However, when light from a projector passes through it, tiny suspended dust particles in the air deflect the light, making the path of the light beam visible. This is proof that the classroom air is actually a heterogeneous mixture. The same effect can also be seen in liquids (**Figure 4**). We can use this evidence to distinguish true solutions from mixtures that appear to be solutions.

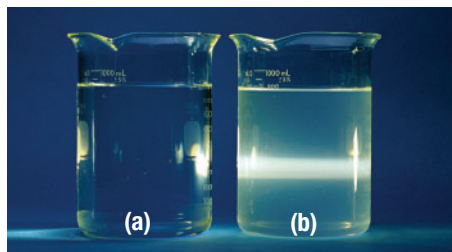


Figure 4 (a) Light passes through the solution but (b) is scattered by tiny suspended entities in a heterogeneous mixture.

Components of a Solution

A solution is a homogeneous mixture of a solute (the substance that is in the lesser quantity) in a solvent (the substance that is in the greater quantity). For the glucose solution in Figure 2, glucose is the solute while water is the solvent. As another example, white rum is a 40 % by volume solution of ethanol (ethyl alcohol). This means that 40 mL of every 100 mL of rum is ethanol. Most of the remainder is water. Therefore, ethanol is the solute and water is the solvent. Alcoholic beverages sold in Canada contain a maximum of 40 % ethanol. In other countries, however, rum may consist of as much as 75 % ethanol. In this case, water is the solute and ethanol is the solvent. Note that a solution may contain more than one solute.

concentration the ratio of the quantity of solute to the quantity of solution or solvent; usually quantity of solute per unit volume of solution

concentrated solution a solution with a relatively large quantity of solute dissolved per unit volume of solution

dilute solution a solution with a relatively small quantity of solute dissolved per unit volume of solution

Perhaps the most important characteristic of solutions is that their composition can change. The term **concentration** is used to describe the ratio of the quantity of solute to the quantity of solution or solvent. A solution that has a relatively high quantity of solute compared to the volume of solution is a **concentrated solution**. A solution with a relatively low quantity of solute compared to the volume of solution is a **dilute solution** (Figure 5).

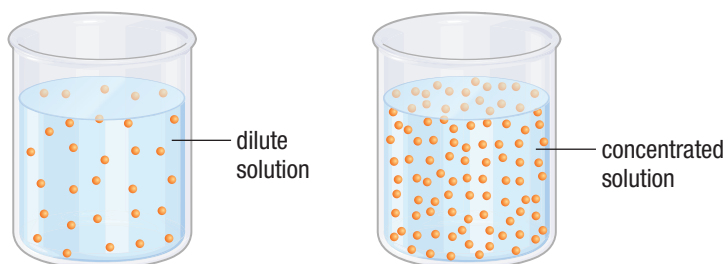


Figure 5 Models of a dilute and a concentrated solution. The concentrated solution contains more dissolved solute per unit volume of solution.

The composition of urine—a solution produced by many animals—varies a great deal. Urine consists of water and dissolved solutes excreted from the body by the kidneys. Changes in the composition of urine can provide important clues that help doctors diagnose medical conditions (Figure 6). If you drink plenty of water, normally functioning kidneys produce dilute urine that is pale yellow in colour. If you are dehydrated, the solutes in urine are more concentrated, resulting in a more intense yellow or orange sample. This can also happen if you eat certain foods. People who regularly consume large doses of water-soluble vitamins produce urine that has a larger than normal concentration of these vitamins. Some nutritionists question the value of consuming large quantities of vitamin supplements, suggesting that the body takes only what it needs. The unneeded water-soluble substances are excreted in the urine. Some diseases can also result in the production of strongly coloured urine, or urine with unusual odours.

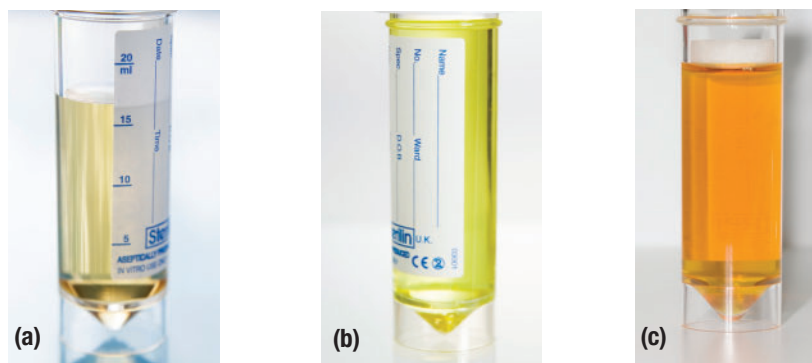


Figure 6 (a) Urine from a healthy, well-hydrated person is usually pale yellow due to urochrome, a compound produced from the breakdown of old red blood cells. (b) If you are dehydrated, urine is darker in colour because the concentration of urochrome is greater. (c) Orange urine may be a symptom of jaundice, a condition that imparts a yellow colour to the eyes and skin. Jaundice is caused by excess bilirubin, a pigment produced by the gallbladder.

Types of Solutions

There are examples of solutions in different states all around you and within you. You already know that air is a gaseous solution consisting mostly of several gases dissolved in nitrogen. You also know that urine is an aqueous solution of many molecular and ionic compounds.

We have considered several examples of aqueous solutions, but there are many liquid solutions in which water is not the solvent. Gasoline is a solution of mostly

liquid hydrocarbons and other solutes. A typical gas station may sell three different grades of gasoline. Each grade has a slightly different composition of solutes, which affects the way the gasoline burns as well as other characteristics. Automobile manufacturers determine the grade that is right for your car.

A solution of two or more metals is called an **alloy**. The gold used for jewellery is alloyed with other metals like silver and copper to stiffen it and produce changes in colour (**Figure 7**). The purity of gold is stated in karats: 24 k gold is pure gold; 14 k gold contains only 58 % gold. 🌐

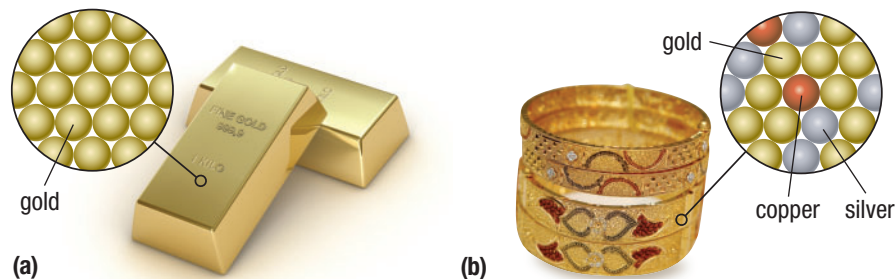


Figure 7 (a) 24 karat gold is pure gold. (b) Most gold jewellery is an alloy of gold and other metals such as copper and silver.

Alloys of mercury are unique because mercury is the only liquid metal at room temperature. As a result, an alloy of mercury is called an **amalgam** to distinguish it from the alloys of other metals. Silver-coloured dental fillings are amalgams of mercury and silver. Mercury also forms an amalgam with gold. If mercury is accidentally spilled on a gold ring it is absorbed by the ring, forming an amalgam. This discolours the gold in the place where the mercury was absorbed.

Solute and solvents can be solid, liquid, or gas. The different possible combinations of solute and solvent result in a variety of solutions. **Table 1** lists examples of some common solute/solvent combinations. Note that metals only form alloys when they are heated until molten (liquid).

Table 1 Classifying Solutions According to Their Solute and Solvents

Examples	Original state of solute	State of solvent
air (oxygen, argon, carbon dioxide, and other gases in nitrogen)	gas	gas
carbonated beverages (carbon dioxide and flavour compounds in water)	gas	liquid
humidity (water molecules in air)	liquid or solid	gas
alcoholic beverages (ethanol in water)	liquid	liquid
silver-coloured dental fillings (mercury amalgams)	solid	liquid
air fresheners (vapours from scented solids in air)	solid	gas
clear apple juice (flavour compounds in water)	solid	liquid
brass (an alloy of copper and zinc)	liquid	liquid

Aqueous Solutions

The most familiar types of solutions are aqueous solutions. An **aqueous solution** contains water as the solvent. (“Aqua” is the Latin word for water.) Most of the solutions used in your investigations are aqueous solutions, as are many common consumer products: pop, vinegar, and clear shampoo, for example. All aqueous solutions are transparent. They can be coloured or colourless. Since they are so common and have such important applications, much of this unit will focus on aqueous solutions.

alloy a solution of two or more metals

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Jewellers are skilled at selecting the appropriate precious metal alloy for each piece they make. They must have a good understanding of the properties of the various alloys. If you are interested in this career,



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amalgam an alloy (solution) of mercury with other metals

aqueous solution a solution in which water is the solvent


Mini Investigation

When Is a Solution No Longer a Solution?

Skills: Performing, Observing, Analyzing

SKILLS
HANDBOOK  A1.1, A1.2, A2.4

The addition of acid to thiosulfate ions in water causes these polyatomic ions to decompose, producing sulfur atoms. Over time these atoms clump together to form visible sulfur particles. In this activity, you will use this reaction to distinguish between solutions and other mixtures that appear to be homogeneous.

Equipment and Materials: chemical safety goggles; lab apron; test tube and stopper; scoopula; 10 mL graduated cylinder; test-tube rack; flashlight (optional); 10 mL distilled water; 2–3 crystals of sodium thiosulfate, $\text{Na}_2\text{S}_2\text{O}_3(\text{s})$; dropper bottle containing dilute hydrochloric acid, $\text{HCl}(\text{aq})$ (0.1 mol/L). 



The hydrochloric acid used in this activity is an irritant. Wash any spills on skin or clothing immediately with plenty of cool water. Report any spills to your teacher.

- Put on your safety goggles and lab apron.
 - Add 10 mL distilled water to the test tube and place it in the test-tube rack.
 - Put 2–3 crystals of sodium thiosulfate in the water. Stopper the test tube and, with your thumb over the stopper, shake the mixture to dissolve the crystals. Record your observations.
 - Remove the stopper and add 3 drops of hydrochloric acid to the test tube. Replace the stopper.
 - Look for changes in the appearance of the mixture over the next 2 min. Record your observations.
 - (Optional) Use the flashlight to shine a beam of light through the test tube. Record your observations.
 - Dispose of the contents of the test tube as directed by your teacher.
- Compare the appearance of the mixture in Step 3 with the mixture produced in Step 5. What can you learn, from your observations, about what type of mixture is present? Explain your answer. T/I
 - Compare the sizes of the entities present in both mixtures. What evidence supports your answer? T/I
 - Is the final mixture a solution? Why or why not? T/I

8.2 Summary

- Only one phase is visible in a homogeneous mixture.
- More than one phase is visible in heterogeneous mixtures. Sometimes magnification is required to identify heterogeneous mixtures.
- A solution is a homogeneous mixture of one or more solutes dissolved in a solvent. Solutions can be solids, liquids, or gases.
- The solvent is the component of the solution that is present in the greatest quantity.
- The concentration of a solution is a measure of the quantity of solute per unit volume of solution.
- A concentrated solution contains a relatively large quantity of solute per unit volume of solvent. A dilute solution contains a relatively small quantity of solute per unit volume of solvent.
- Solutions of metals are called alloys.

8.2 Questions

- Classify the following as solutions, heterogeneous mixtures, or pure substances: **K/U T/I**
 - chlorinated pool water
 - sodium chloride
 - a jar of jelly beans
 - latex paint
 - propanone (acetone)
 - compressed air in a scuba tank
 - chlorine bleach
 - a silver-coloured dental filling
 - pure liquid honey
 - 24 karat gold
- Use a familiar consumer product as an example to illustrate the difference between the terms “solute” and “solvent.” **K/U A**
- Identify the solute(s) and solvent in each of the following solutions: **K/U T/I**
 - salt water
 - carbonated water
 - a 3 % aqueous solution of hydrogen peroxide
- Figure 8** shows shafts of light passing through mist. Classify the air in this photo as being a solution or heterogeneous mixture. Justify your choice. **K/U T/I**



Figure 8 Suspended water droplets and dust particles scatter the light, making shafts of sunlight visible.

- You are given two clear, colourless liquids. You are told that one of them is an aqueous solution containing a solid solute. The other one is a pure substance. **T/I**
 - Predict what you would observe when the liquids are slowly evaporated.
 - Suggest another test that you could perform on the liquids to identify which is the aqueous solution.
- Why are heterogeneous liquid mixtures translucent or opaque while liquid solutions are transparent? Illustrate your answer with sketches. **K/U C**
- Distinguish between an amalgam and an alloy. **K/U**
- Water and ethanol are both clear, colourless liquids. When 50 mL of ethanol is combined with 50 mL of water, the final volume of the resulting solution is 96 mL. Assume that no evaporation or spillage occurred. Consider what is occurring at the molecular level when these liquids combine. Suggest an explanation to account for the lower-than-expected volume. **T/I**
- What effect do the following changes have on the concentration of a solution? Justify your answer in each case. **K/U T/I**
 - adding more solute
 - adding more solvent
 - heating the solution to evaporate some of the solvent
 - dividing the solution between two different containers
- Mercury is a highly toxic substance and yet many dentists routinely use mercury amalgams in dental fillings (**Figure 9**). Get the facts! Seek out a few reliable sources and evaluate the dental use of mercury amalgams. Prepare a one-paragraph summary of your evaluation. **T/I A**



Figure 9 In June 2010, the U.S. Food and Drug Administration (FDA) reopened the debate regarding the safety of mercury amalgam fillings. Are they safe?



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