

MIXTURES AND PHASE CHANGES

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Reader's Theater

The Science of Lemonade

Setting: Adam and Zena are at their Aunt Lucy's house after school with Olivia, mixing up some pink lemonade from a powder mix.

Olivia: Where's a pitcher? I'll fill it with water.

Zena: Nope, I make mine separately, because Adam makes it too sweet.

Adam: You don't make it sweet enough.

Zena: Yuck! Don't listen to him. Here's the right way to make it: Put four teaspoons of pink lemonade powder into a glass, like this, and then fill the glass with water. Perfect!

Olivia: Okay. How many teaspoons of powder do you use per glass, Adam?

Adam: Oh, I don't measure, exactly. I just eyeball it. I put water into the glass, like this... Then I shake some powder out of the package, like this...and stir it a bit. Look at the color. It's about as pink as Zena's, which means it's not as sweet as I like it.

Olivia: That's kind of interesting: You can "see" how sweet it is by looking at the color.

Adam: Right. The **concentration** of sugar and of food coloring in the lemonade go together. If you add more powder, the sugar **concentration** and the pink food coloring **concentration** both go up. So I add a bit more powder and stir again. There! It's a nice dark pink. That should be good... Yup! Tastes about right.



Zena: Suit yourself, Adam. Olivia, let's get you a drink.

Olivia: Thanks. I'm not sure how much of the powder to use. I guess I'll try four teaspoons, like Zena. It'll be easier to add more powder and make it sweeter than to take it out once it's mixed in. (*Olivia makes herself some lemonade and takes a sip.*) Hmm. Actually, even that is a little too sweet for me.

Zena: If you want it less sweet, you can just **dilute** it with a little more water.

Olivia: "Dilute"?

Zena: Yeah, **dilute**: Make it less **concentrated**.

Adam: Sure. You'll have the same amount of powder mix dissolved in your glass, but when you **dilute** it with more water it'll be less **concentrated**.

Olivia: There! It's not as pink now...and it's not as sweet. Good.

Zena: Hey, do you think that when we mix the pink lemonade powder in with the water, we get a chemical reaction, like we were learning about last week in Ms. Quintanilla's class? I mean, we're making a new substance, right?

Olivia: What new substance? Pink lemonade? That's just water with sugar, flavoring, and coloring mixed in, isn't it? I don't think we're making a chemical reaction and producing some kind of pink lemonade molecules...are we?

Zena: Why not? There's obviously some kind of change, and we learned in class that chemical reactions change matter. Maybe water reacts with the powder and makes a new compound.

Adam: Well, wait a minute. I don't think pink lemonade can be a compound. Look at our three glasses. Mine is the darkest pink and sweetest. Olivia's is the palest pink and the least sweet. And Zena's is in between. We learned that a compound combines different elements in *definite proportions*: all water has two atoms of hydrogen per one atom of oxygen, and so on. But we've got three samples of pink lemonade and each one combines its ingredients in different proportions. So if pink lemonade doesn't have definite proportions, I don't think it can be a compound.

Olivia: Yeah, I think it's just water with powder dissolved in it.

Zena: So is "dissolving" not a kind of chemical reaction? It's definitely a change. Is dissolving a kind of change that doesn't involve a chemical reaction?

Adam: I think it could be. We did learn that not all changes in matter are chemical reactions. Remember: When a nail rusts, that's a chemical reaction, but when it just bends, that's a physical change that's not a chemical reaction. So maybe dissolving is another kind of physical

Reader's Theater

The Science of Lemonade

change that doesn't involve making new compounds. Maybe dissolving just mixes the molecules of different compounds together.

Olivia: The powder has sugar molecules, and I suppose the coloring and flavoring also come in the form of molecules. Maybe all those molecules just get mixed in with the water molecules. And if the molecules don't change, there's no chemical reaction.

Zena: Hmm. Okay, maybe mixing the molecules of the water and the pink lemonade mix is like mixing white rock gravel and black rock gravel. You could mix white and black gravel in different **concentrations** and get mixtures that would be different shades of gray when you looked at them from a distance. But there wouldn't actually be any grey rocks; the white and black rocks would all be the same as before. Maybe our glasses of lemonade are like that.

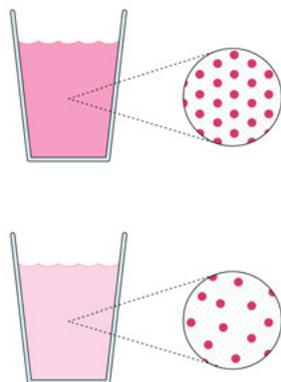
Adam: Well, I'm not sure. But I've got a **solution**. Hey, Aunt Lucy?

Aunt Lucy: (*coming into the kitchen*) Hi guys. What's up?

Adam: We were wondering whether you get a chemical reaction when you stir pink lemonade powder into water. We figured if there was a chemical reaction, there would have to be a new compound, and we weren't sure whether pink lemonade is a compound, because it isn't made with consistent proportions of ingredients. Some pink lemonade is **diluted**, like the weak stuff Zena likes...

Zena: And some is more **concentrated**, like that sickeningly sweet stuff Adam drinks.

Concentration is a **rate**: There are more food coloring, sugar, and flavoring molecules **per unit of volume** in highly **concentrated** pink lemonade than in less **concentrated**, more **dilute** pink lemonade.



Aunt Lucy: Um, okay. Well, when we talk about **concentration**, we're usually talking about a chemical **solution**, not a compound.

Olivia: A **solution** like the answer to a problem?

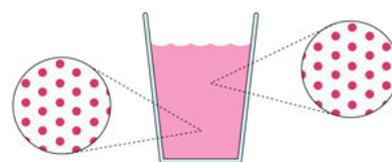
Aunt Lucy: No, I'm using the word **solution** in a different sense, related to the word "dissolve." A **solution** is what you get when you put compounds together and instead of a chemical reaction you get a **homogeneous** mixture. In a **homogeneous** mixture, the particles are evenly mixed together, the way the water molecules, sugar molecules, flavor molecules, and coloring molecules are in the pink lemonade. Samples taken from different parts of a **homogeneous** mixture will be exactly the same.

Adam: So are all mixtures **homogeneous**?

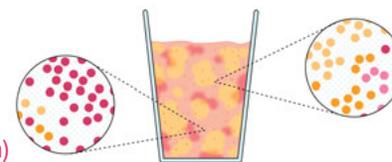
Olivia: No, I don't think that would make sense. If we made a smoothie in a blender and you took a sip, you might get a lump of banana. In another sip, you might get more strawberry, or more orange juice, or whatever ingredients you mixed into your smoothie.

Aunt Lucy: Right. A smoothie would be an example of an uneven, lumpy, **heterogeneous** mixture. Samples taken from different parts of a **heterogeneous** mixture may have different substances.

Homogeneous pink lemonade mixture (a **solution**)



Heterogeneous fruit smoothie mixture (not so smooth at a molecular level, so **not** a **solution**)



Zena: So when stuff dissolves and makes a **solution**, is that a kind of chemical reaction?

Aunt Lucy: No, dissolving is usually thought of as a physical change, not a chemical reaction. There are other physical changes, too, like when a substance changes from solid to liquid to gas—for example, water changing from ice to liquid water to steam. Those are called **phase** changes. A substance doesn't change its chemical composition just because it melts or evaporates. Water is still H₂O, whatever **phase** it's in.

Reader's Theater

The Science of Lemonade

Olivia: And water is still H₂O even when it's got sugar molecules and other molecules from pink lemonade powder dissolved in it. It's still water, even though it's not pure water.

Aunt Lucy: Exactly. In fact, you can divide substances into pure and impure substances. Elements and compounds are pure substances. Another name for pure substances is "chemicals." Mixtures are impure substances, because they combine two or more pure substances. Within mixtures, you have **homogeneous** mixtures (also called **solutions**) and **heterogeneous** mixtures.

Zena: Wait, slow down. Let me grab some paper. Can you repeat that? We're supposed to make a poster

about chemistry in Ms. Quintanilla's class for next Tuesday. If we use these categories, maybe we can make a kind of map for categorizing all kinds of matter.

Olivia: I think I'll do my poster on **concentration**. I can do the whole thing with pink lemonade!

Aunt Lucy: And I think I'll have a spoonful of this pink lemonade powder. I like it straight up, with no water!

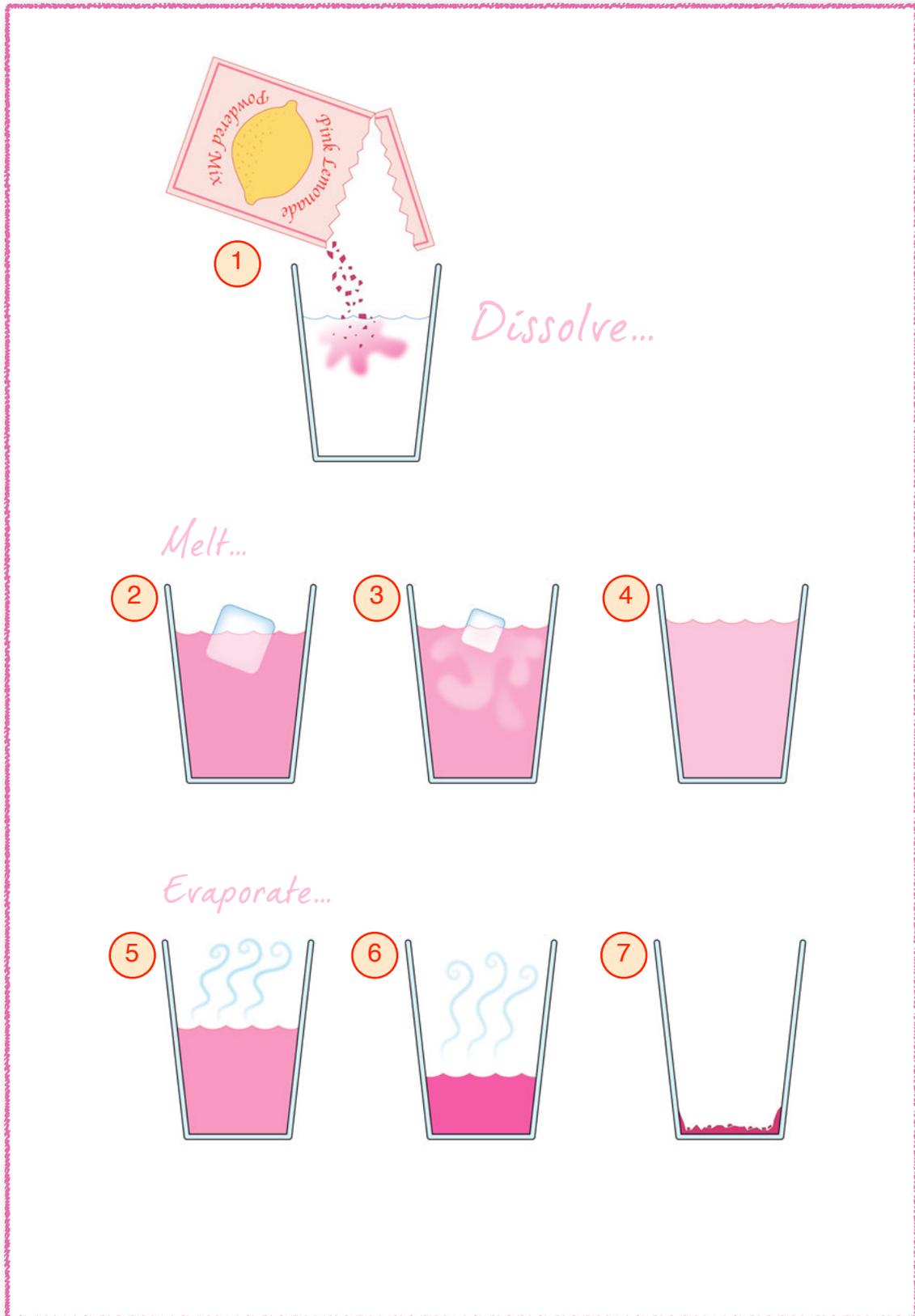
Adam: Go Aunt Lucy! Now that's what I'm talkin' about!

Zena and Olivia: Eeeeeew!



A Closer Look at Concentration

Olivia's Poster



A Closer Look at Concentration

Olivia's Poster

Olivia's poster on **concentration** shows a simple story: Pink lemonade powder is poured into water to make a **solution**, and ice is added to cool it. But then the glass of lemonade gets left in a sunny spot for several days, with nobody drinking any of it. First the ice melts, and then eventually all the water evaporates, leaving the powdered mix re-solidified in the bottom of the glass.

TURN AND TALK

With a partner, help Olivia fill in some information to go along with the illustrations on her poster. (Thinking about how to fill in these blanks will help prepare you to consider a more serious **concentration** problem on the next page: drunk driving.)

As the ice melts into the solution...

What happens to the volume of the **solution**?

What happens to the amount of sugar, flavoring, and coloring molecules in the **solution**?

What happens to the **concentration** of the **solution**?

As the water evaporates from the solution...

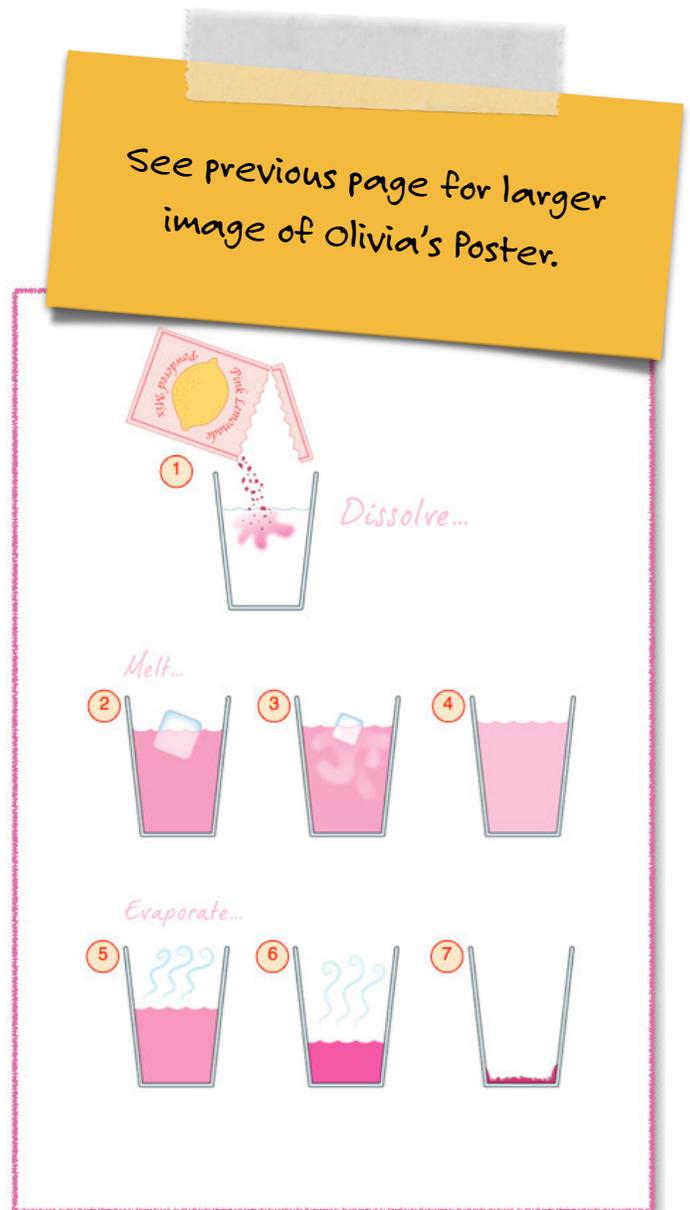
What happens to the volume of the **solution**?

What happens to the amount of sugar, flavoring, and coloring molecules in the **solution**?

What happens to the **concentration** of the **solution**?

At which step are the contents of the glass **most concentrated and sweet**?

At which step are the contents of the glass **most dilute and unsweet**?



Speaking Scientifically

A Map of Matter

Below is a diagram Zena made showing how different categories of matter fit into one another. In her diagram, more specific categories are nested inside of more general ones. Pretty much all the materials around you, and even in you, fit into one of the four categories in the diagram's white areas. In this section, we're focusing on the mixtures.



BRONZE
HELMET



STEEL BEAM



CARBONATED WATER

Homogeneous mixtures (solutions)

Mixtures with substances dissolved evenly into one another, like pink lemonade powder dissolved in water, are called **homogeneous** mixtures, or **solutions**.

It might surprise you to learn that **solutions** don't necessarily have to be made of a solid dissolved in a liquid. There can be solids dissolved in solids. For example, "alloys" are metals made by evenly mixing different metals together, or sometimes by mixing nonmetallic elements into metals. Alloys are mixed together while metals are melted, but they remain evenly mixed **solutions** when they cool and solidify. Bronze is a **homogeneous** mixture of copper (Cu) and tin (Sn). Steel is an alloy made by mixing a little carbon (C, a nonmetal), and sometimes other elements, into iron (Fe).

Gases can be dissolved in gases. For example, the air you breathe is a **solution** of oxygen gas (O₂), carbon dioxide gas (CO₂), and other gases dissolved in nitrogen gas (N₂). Apart from varying amounts of water vapor, "dry" air is about 78 percent nitrogen gas and 21 percent oxygen gas.

Gases can also be dissolved in liquid. For example, carbonated drinks have carbon dioxide (CO₂) dissolved in water (H₂O).

Liquids can be dissolved in liquids. Alcohol and water, for instance, will blend evenly into a **solution**.

Heterogeneous mixtures

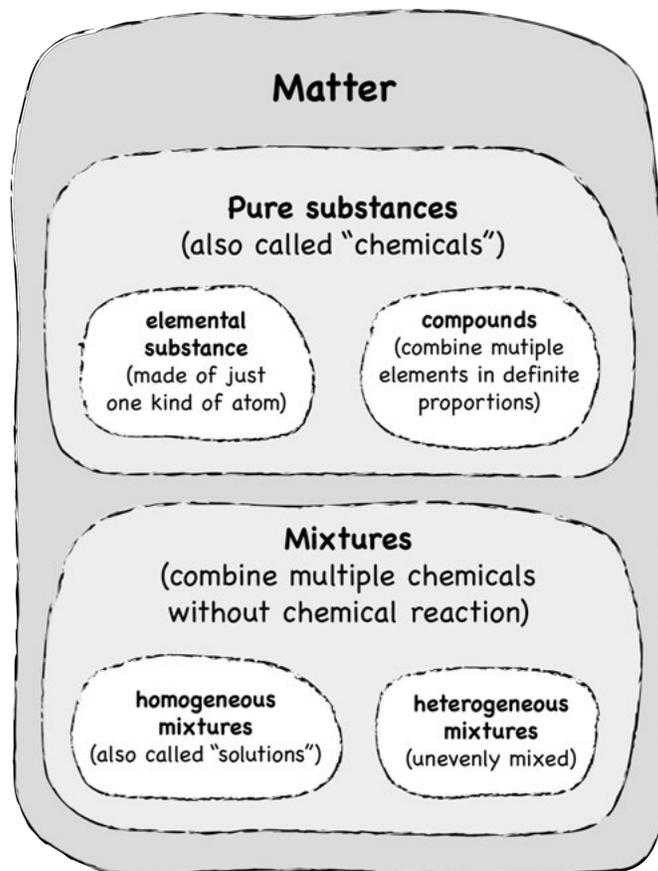
Some substances, like oil and water, cannot dissolve into one another. Vinegar is made mostly of water (with acetic acid and various flavoring molecules), so oil and vinegar salad dressings are **heterogeneous** mixtures.

The world is full of **heterogeneous** mixtures. For example:

- concrete made with sand and other materials mixed together
- food with various ingredients stirred together but not perfectly dissolved
- dirt with tiny pieces of minerals and organic matter and pockets of air
- wood with solid fibers and tiny vessels carrying sap



OIL AND VINEGAR

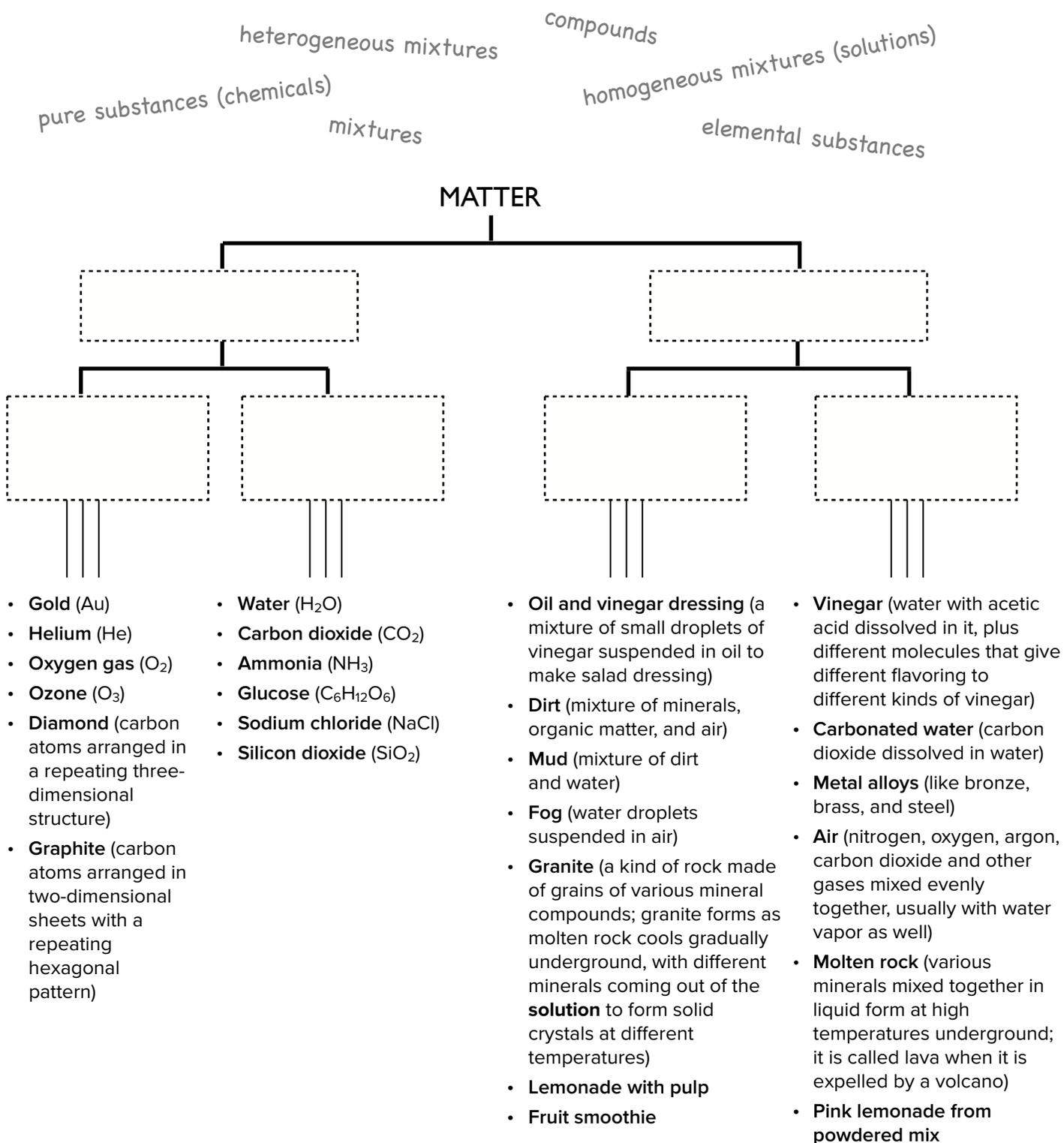


Speaking Scientifically

Name that Category

With a partner, examine the chart below. It represents the same categories as Zena’s diagram, but most of the important labels are missing. This version is constructed like a flow chart or a family tree and has examples of each category of matter. Go over the examples at the bottom of the chart and work your way up, figuring out what label belongs in each blank box.

Here are the six terms to use to fill in the blanks:



Speaking Scientifically

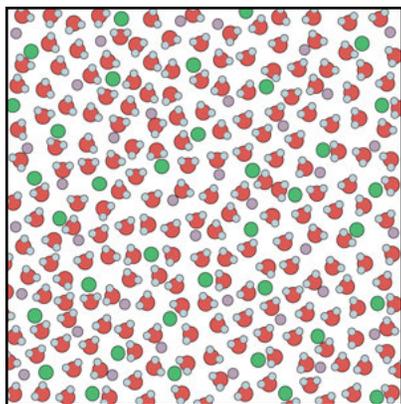
Seaside Mixtures

TURN AND TALK

Take a look at these particulate views of mixtures by the seashore. With a partner, talk about which mixtures you think are **homogeneous** and which you think are **heterogeneous**.

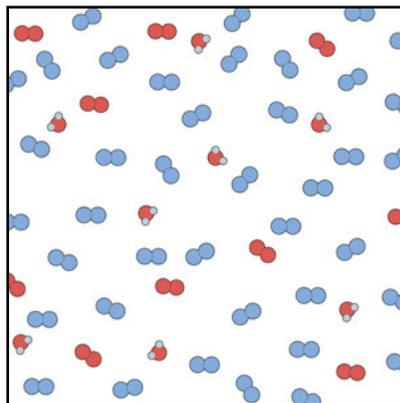
SALT WATER

Salts like sodium chloride (NaCl, shown) dissolved in water. Sodium atoms are attracted to the oxygen atoms in water molecules, and chlorine atoms are attracted to the hydrogen atoms, pulling the sodium chloride apart.



AIR

About 78% nitrogen gas (N₂) and 21% oxygen gas (O₂), with smaller amounts of other gases including water vapor, carbon dioxide, and argon.

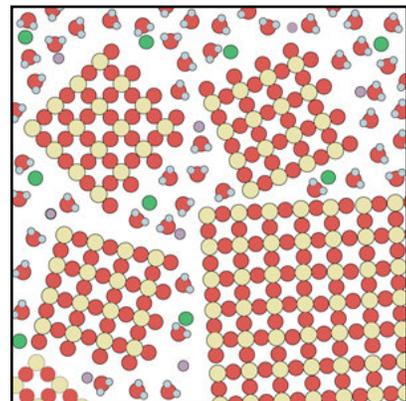
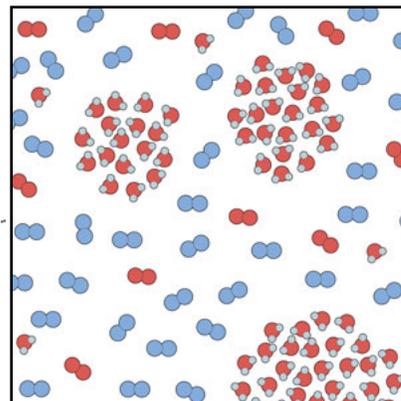


Elements shown

- chlorine (Cl)
- sodium (Na)
- hydrogen (H)
- oxygen (O)
- silicon (Si)
- nitrogen (N)

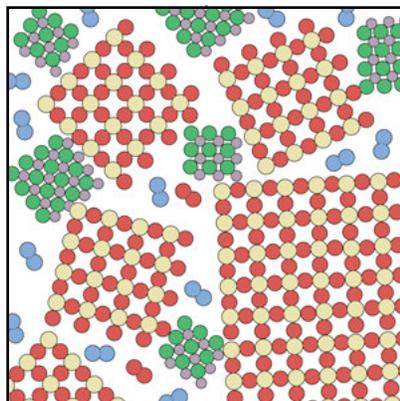
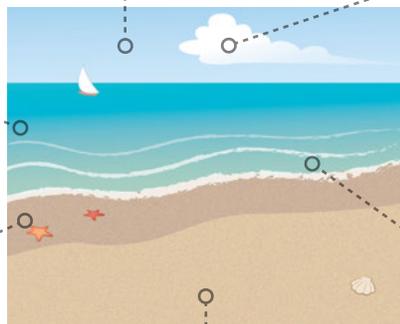
CLOUD

Microscopic droplets of liquid water suspended in AIR.



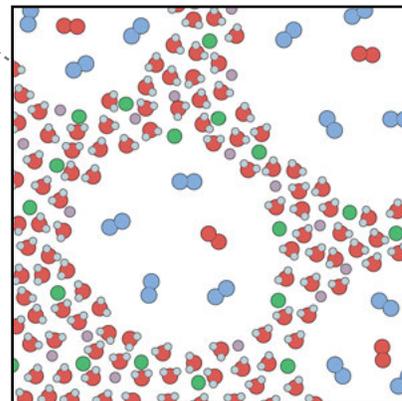
WET SAND

Pieces of solid silicon dioxide (SiO₂), mixed with **SALT WATER**.



DRY SAND

Pieces of solid silicon dioxide (SiO₂), mixed with salt crystals and AIR.



FOAM ON WAVES

Bubbles of AIR surrounded by **SALT WATER**.

Note: These illustrations are not drawn to scale: A water droplet in a cloud has many more water molecules than shown here, a grain of sand has many more oxygen and silicon atoms, etc.

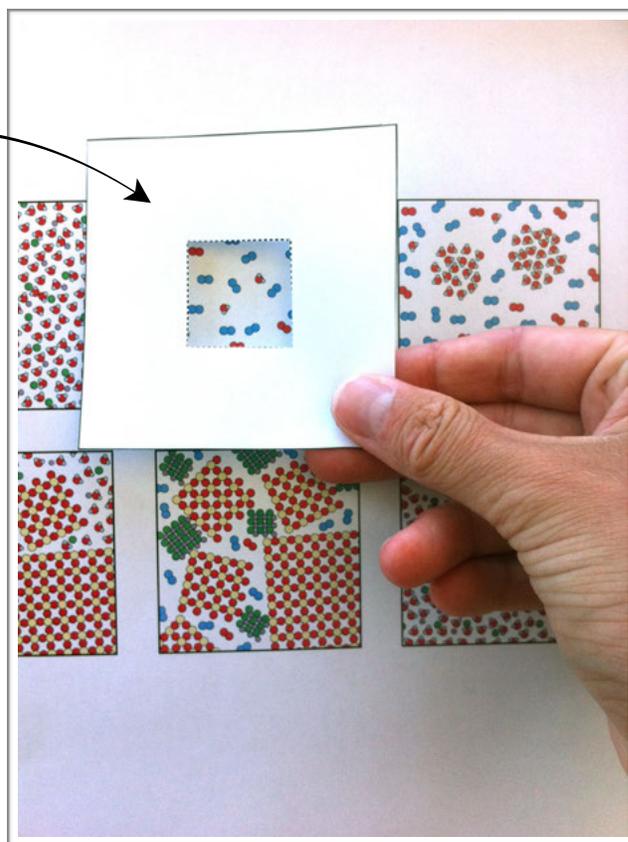
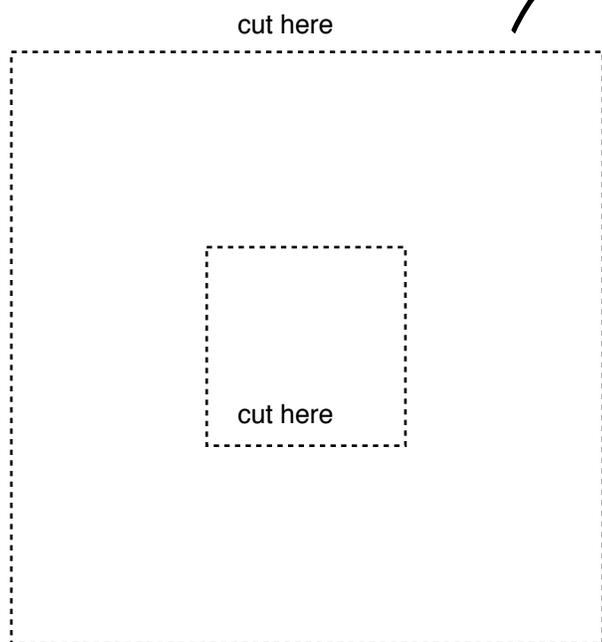
Speaking Scientifically

Looking Through a Particulate Window

To help you decide which mixtures are **homogeneous** and which are **heterogeneous**, cut out the viewing frame below and move it over each picture on the pages that follow. Does the makeup of particles look about the same no matter which part of the image you sample? If so, the mixture is an even, **homogeneous** mixture (a **solution**). Does the mixture look different depending on which part you sample? If so, it is an uneven, **heterogeneous** mixture.

As you and a partner use the viewing frame to compare samples of the particles in each illustration, fill out the worksheet on the following pages. Say whether each mixture is **homogeneous** or **heterogeneous**. Explain your reasoning. Talk about what chemicals are found in each mixture and how they are mixed together in each case.

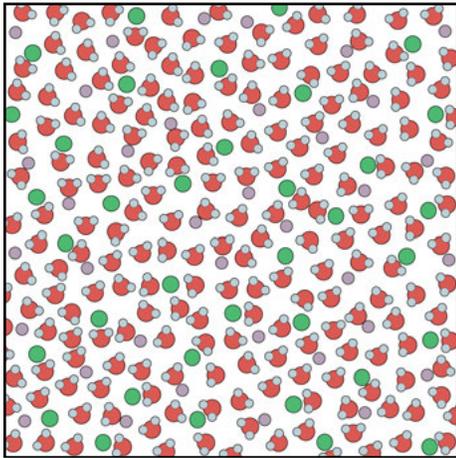
Cut out the viewing frame below and use it to look at the illustrations of the different seaside mixtures, as in the photograph.



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Speaking Scientifically

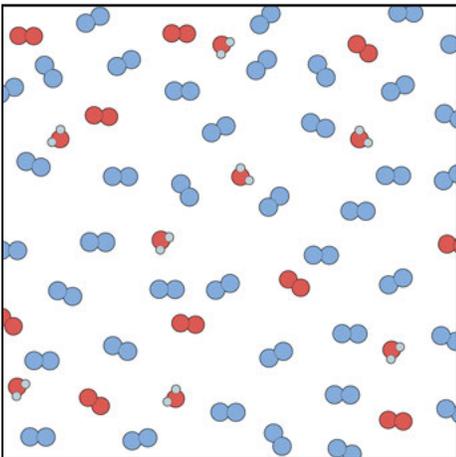
Looking Through a Particulate Window



SALT WATER

Salts like sodium chloride (NaCl) dissolved in water. When dissolved in water, the sodium and chlorine atoms are pulled apart from each other because of their attraction to different parts of the water molecules. The sodium atoms are attracted to the oxygen atoms in water molecules, and chlorine atoms are attracted to the hydrogen atoms.

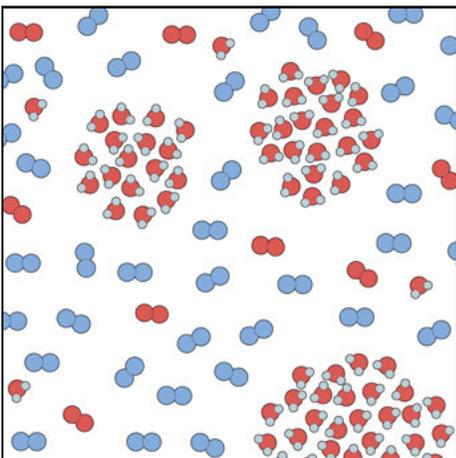
Is this mixture **homogeneous** or **heterogeneous**? Explain:



AIR

About 78% nitrogen gas (N₂) and 21% oxygen gas (O₂), with smaller amounts of other gases including water vapor, carbon dioxide, and argon.

Is this mixture **homogeneous** or **heterogeneous**? Explain:



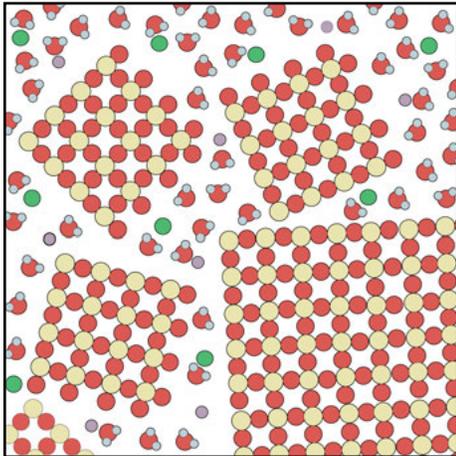
CLOUD

Microscopic droplets of liquid water suspended in **AIR**.

Is this mixture **homogeneous** or **heterogeneous**? Explain:

Speaking Scientifically

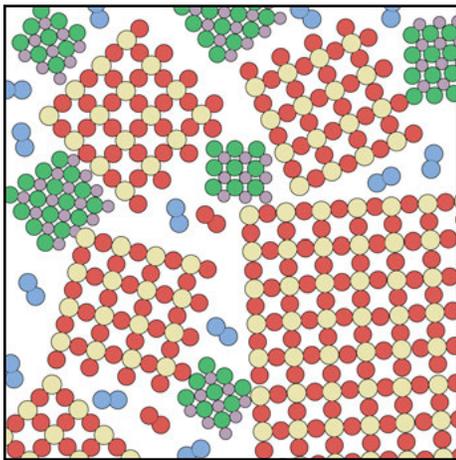
Looking Through a Particulate Window



WET SAND

Pieces of solid silicon dioxide (SiO₂), mixed with **SALT WATER**.

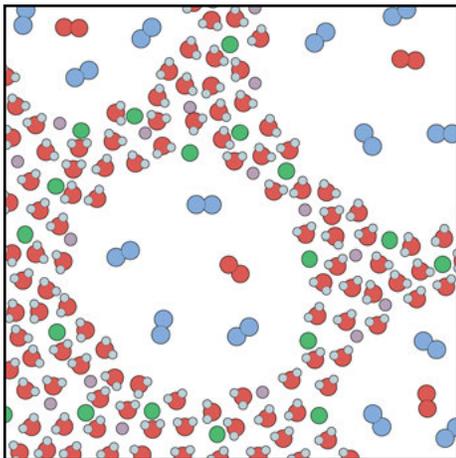
Is this mixture **homogeneous** or **heterogeneous**? Explain:



DRY SAND

Pieces of solid silicon dioxide (SiO₂), mixed with salt crystals and **AIR**.

Is this mixture **homogeneous** or **heterogeneous**? Explain:



FOAM ON WAVES

Bubbles of **AIR** surrounded by **SALT WATER**.

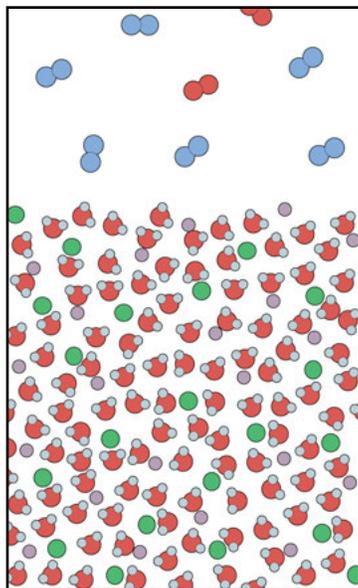
Is this mixture **homogeneous** or **heterogeneous**? Explain:

Going Through Phases

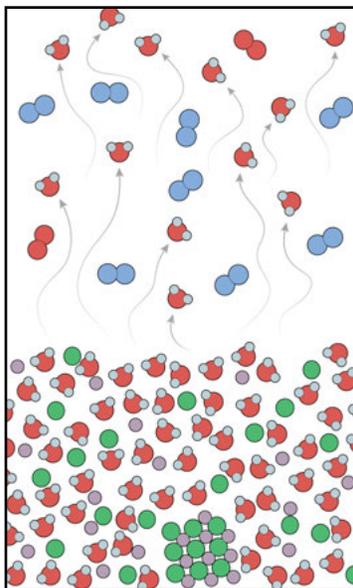
Concentrating on Evaporation

For chemists, one thing that distinguishes a mixture from a compound is that the ingredients in a mixture can be taken apart by a *physical process*, while the ingredients of a compound can only be taken apart by a *chemical reaction*. You can get solid salt out of a saltwater mixture by evaporating the water molecules away, a physical process requiring no chemical reaction. This evaporation might be caused by, for example, sunlight heating the water, so that many of the water molecules get enough energy to escape the salt water and fly into the air.

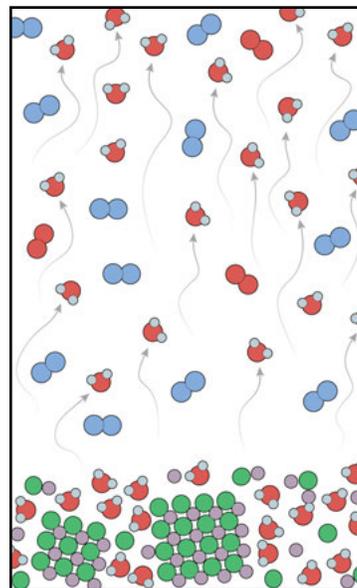
1 Salt water, with air above (mostly nitrogen & oxygen gas)



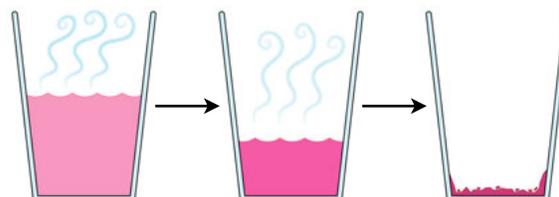
2 Some water molecules evaporate into the air...



3 More water molecules evaporate into the air...



Question: What happens to the saltwater **solution** as water molecules evaporate but sodium and chlorine atoms do not? Refer to the three pictures above, and use the words “**concentration**” and “**dilute**” in your explanation.



Hint: Remember what happened to the evaporating pink lemonade?

Going Through Phases

Fresh water from the sea?

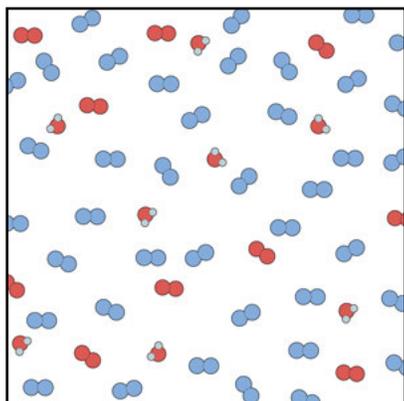
Water, water, every where,
Nor any drop to drink.

—Samuel Taylor Coleridge, *The Rime of the Ancient Mariner*

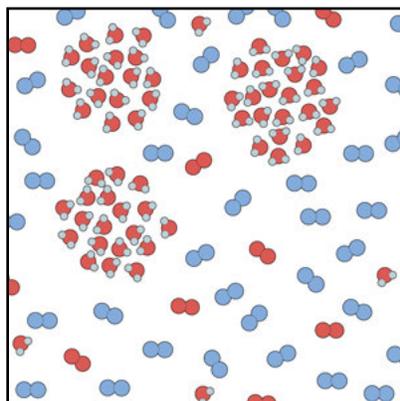
You can get salt out of seawater through evaporation. But what if what you really want is the *water* without the salt? The world has oceans full of salt water, but salt water isn't much use for drinking or agriculture. People need fresh water (that is, non-salty water), but fresh water is in short supply in many places. One possible **solution** is to get fresh water from seawater, leaving behind the salt. There are several ways to do this, one of which is a process called distillation.

Distilling seawater starts with the same process used for getting solid salt out of seawater: evaporation. Evaporation separates the water from the salt. But you can't drink water vapor directly out of the air. You also need to get the molecules of the water vapor to join back together into their drinkable, closely-packed liquid form, a process called condensation:

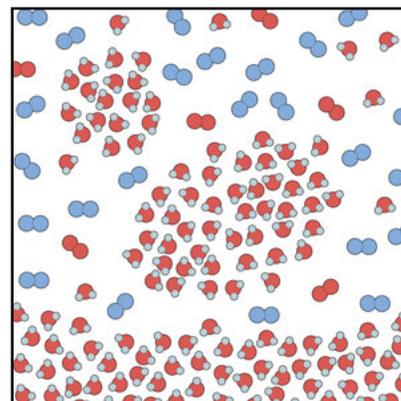
1 Water vapor in air...



2 condenses into cloud droplets...

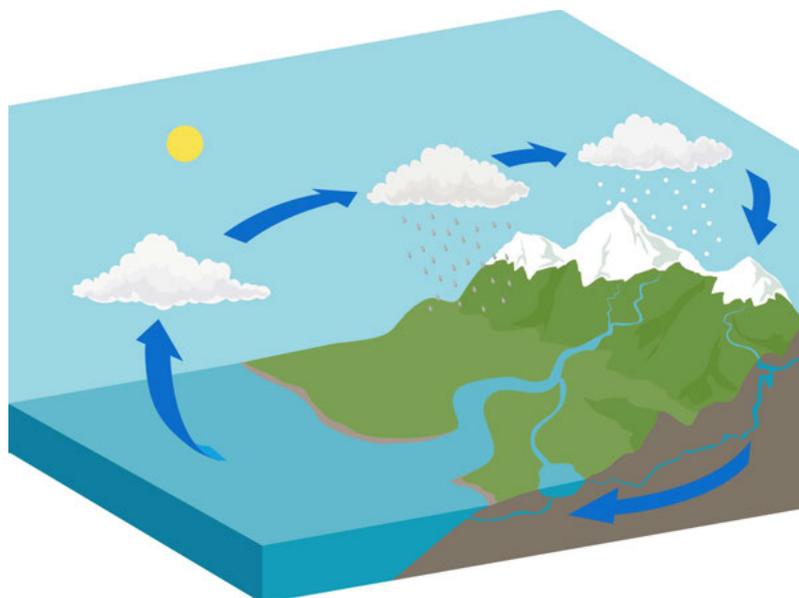


3 and falls down.



The higher the **concentration** of water vapor in the air, and the colder the air is, the easier it is for water molecules to clump together into a more dense liquid form. That's what puts the **density** in condensation!

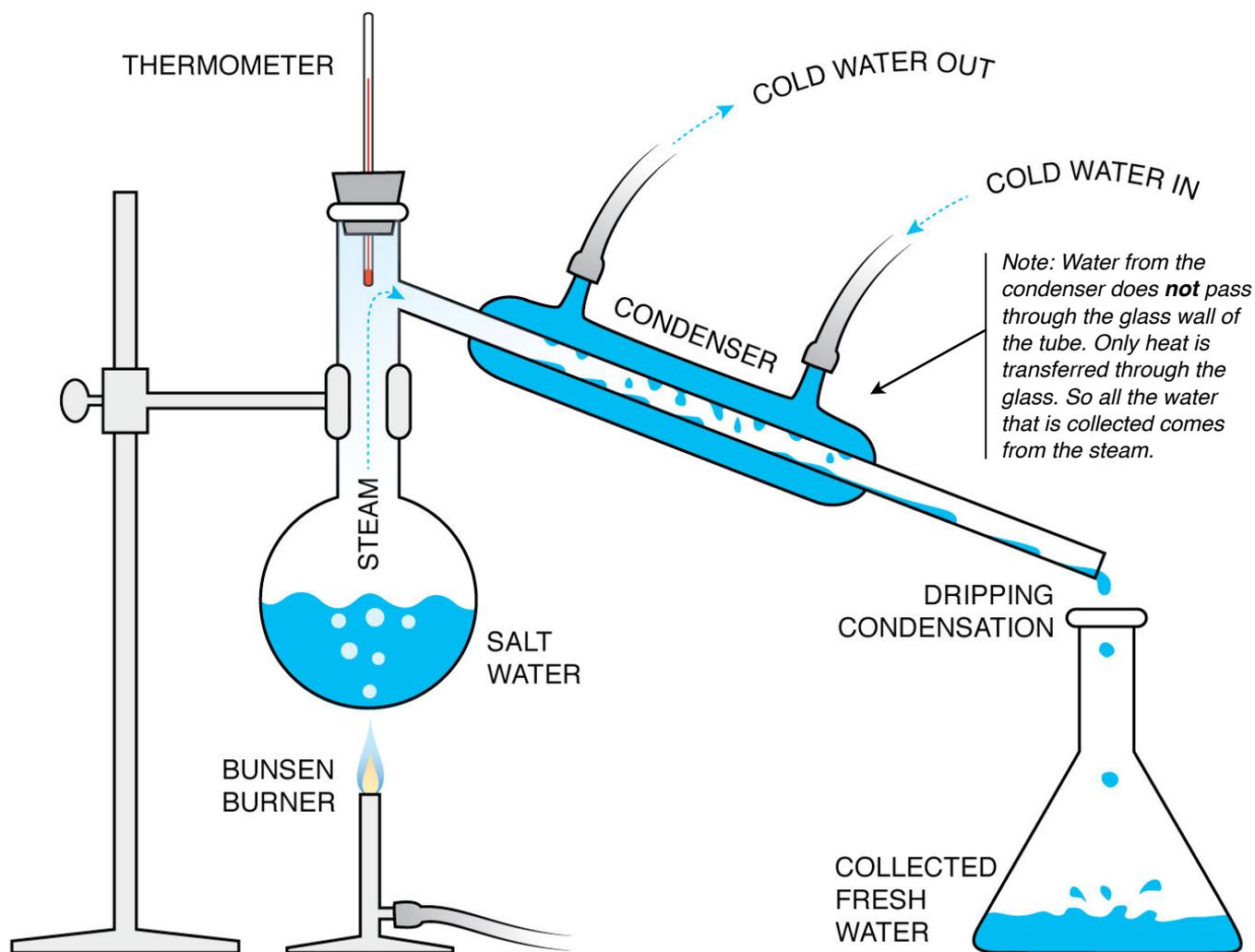
So you get the salt water to evaporate by heating it, and then you get the water vapor to condense into liquid fresh water by cooling it. Nature runs this kind of distillation process all the time on a huge scale. The sun causes water to evaporate from the ocean, and then fresh water condenses into clouds and falls as rain or snow. That's where all the fresh water in rivers, lakes, and underground aquifers ultimately comes from.



Going Through Phases

Fresh water from the sea?

On a much smaller scale, a simpler distillation apparatus can be set up in a lab. The illustration below shows a beaker of salt water being heated with a bunsen burner. Steam (pure H_2O) rises, leaving the salt behind. When the steam gets into the glass pipe that is angled downward, it transfers its heat through the glass to cold water circulating in the surrounding condenser. Only heat passes between the pipe and the condenser, not water. In effect, the condenser is just a cold sleeve wrapped around the angled glass pipe. The cooled steam inside the pipe condenses and drips into a collection flask.



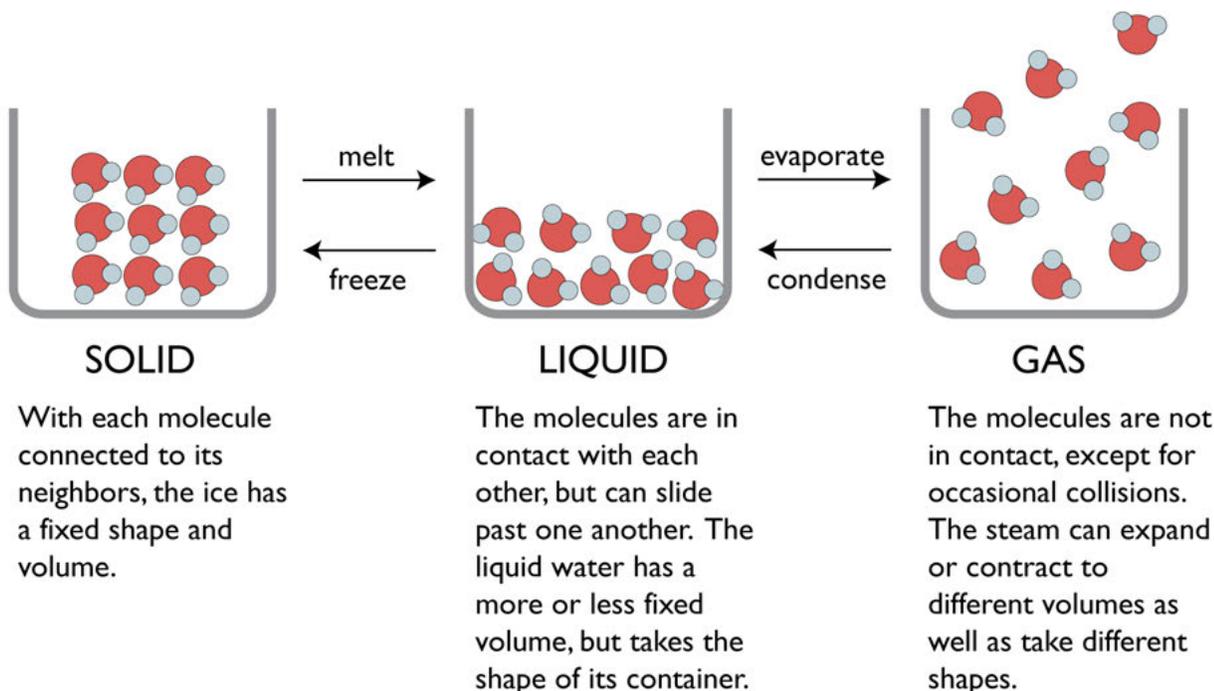
TURN AND TALK

How is the distillation apparatus illustrated above similar to the water cycle in nature? Specifically, which parts of the lab apparatus correspond to the sun, the ocean, cloud formation, rain, and rivers and lakes?

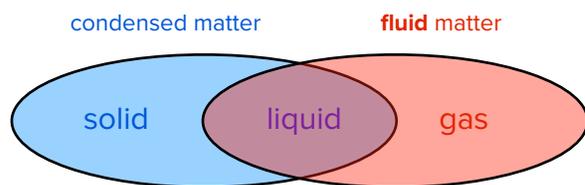
Going Through Phases

Phase Changes

Evaporation and condensation are both physical changes. More specifically, they are **phase** changes. **Phase** changes are changes between the solid, liquid, and gaseous forms of a substance. The most familiar example of **phase** changes is water:



Solids and liquids are both *condensed phases* of matter, with particles in continuous contact with each other. Liquids and gases are both *fluid phases* of matter, with particles able to change position relative to each other.



Notice that liquids are *both* condensed *and* fluid!

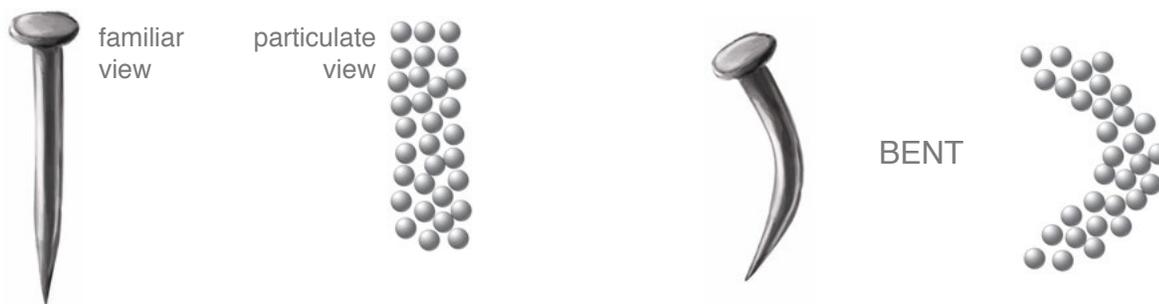
TURN AND TALK

When car mechanics talk about checking the **fluids** in a car, they generally mean the motor oil, transmission **fluid**, brake **fluid**, power steering **fluid**, coolant, and windshield washer **fluid**. How is this use of the word “**fluid**” different from the scientific definition of the word? What word could people use to be more scientifically precise about the “**fluids**” in cars? Should checking the air pressure in a car’s tires be considered part of checking the car’s **fluids**?

Density

Heating Up and Spreading Out

When an iron nail rusts, it undergoes a chemical reaction. But when it bends, that's just a physical change, not a chemical reaction. There's no change in chemical composition: It's still just a bunch of iron atoms.

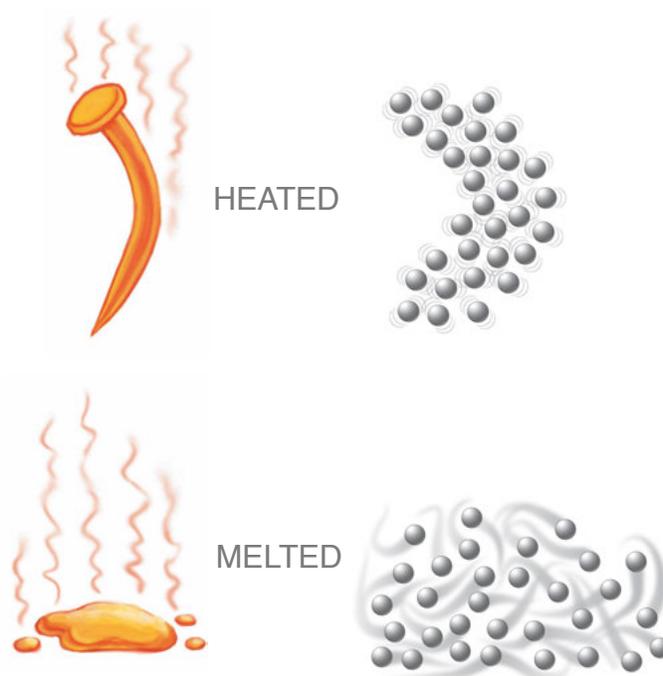


The iron nail can illustrate other physical changes. It can undergo expansion and even **phase** changes when its temperature is raised.

As the temperature climbs, the iron atoms move faster, bump into each other harder, and push each other away. They remain stuck in their relative positions, but their increased vibration causes the nail to expand slightly.

Suppose you heat the iron nail even more. At some point, the atoms have so much energy, and move so violently, that they're completely knocked out of position. They start to slide past each other. They are still in contact with each other (so they're in a condensed **phase**), but they can change position relative to each other (so they're in a **fluid phase**). The **phase** which is *both* condensed *and* fluid is the *liquid phase*.

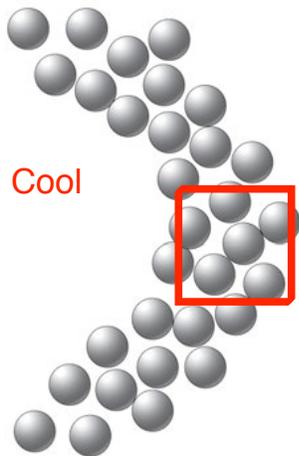
If you could somehow heat the iron all the way up to 4982° F, the atoms would batter each other so hard that they would bounce off and lose direct contact with each other. You would have iron gas!



Density

Heating Up and Spreading Out

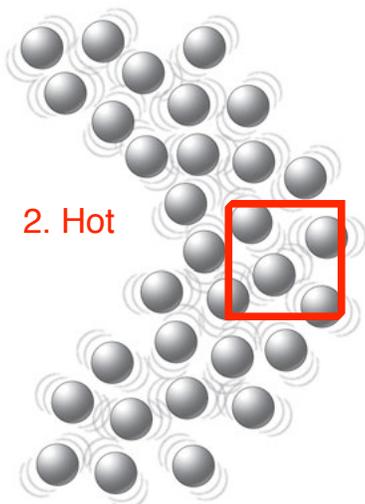
1. Cool



Look again at the three illustrations of iron atoms at different temperatures. All the iron atoms are the same size, and there are 31 of them in each illustration. Those atoms take up more space as they heat up, move faster, and bounce off each other harder. There are the same number of atoms, just spread out more.

Each of the three illustrations has a square drawn over it. The three squares are the same size. What happens to the number of atoms inside the squares as you go from cooler to hotter?

2. Hot



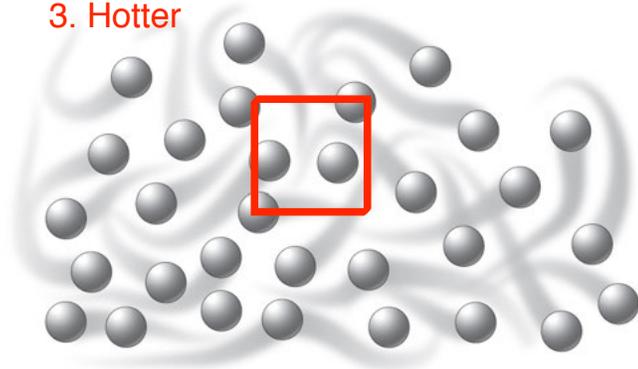
As an iron nail heats up and expands its overall volume, one cubic centimeter of its substance has fewer atoms. With fewer atoms, one cubic centimeter of its substance has less mass, even though the overall mass of the expanded object is the same as before.

The ratio of mass to volume is called **density**. Put another way, **density** is mass divided by volume. So an iron nail becomes less dense as its temperature climbs.

Density = mass / volume

For example, **density** is often measured in grams per cubic centimeter (g/cm^3).

3. Hotter



Iron at room temperature has a **density** of about $7.87 g/cm^3$. For the following questions, assume the iron remains at room temperature.

What is the mass of three cubic centimeters of iron?

What is the volume of 15.74 grams of iron?

Density

Floating in Air

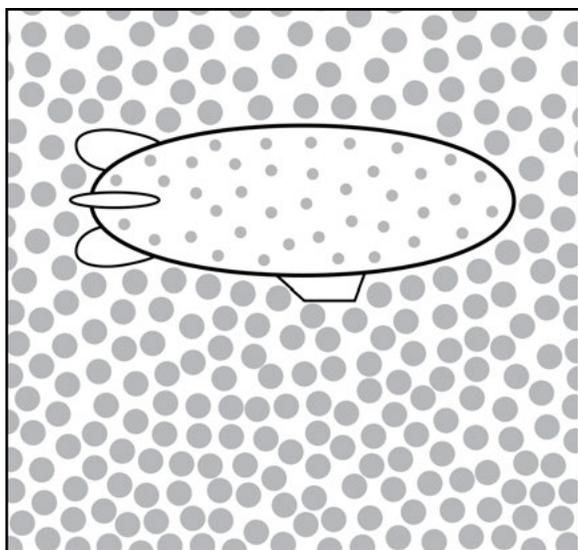
As you've seen with iron, the **density** of a substance can change with its temperature. But different materials at the same temperature also have different **densities**. If you have a cubic foot of lead, a cubic foot of water, and a cubic foot of Styrofoam all at the same temperature, they'll have very different masses, because they have very different **densities**.

Two ways to float in the air

An object placed in a **fluid** will float if it's less dense than the **fluid**, and sink if it's more dense than the **fluid**. Remember, a **fluid** can be either a liquid or a gas. The typical cases we see around us are things that float or sink in air, and things that float or sink in water. Iron is so dense that it sinks in water, whereas helium floats in air because it is less dense than air. Cork is less dense than water but more dense than air, so it floats on water but not in air.

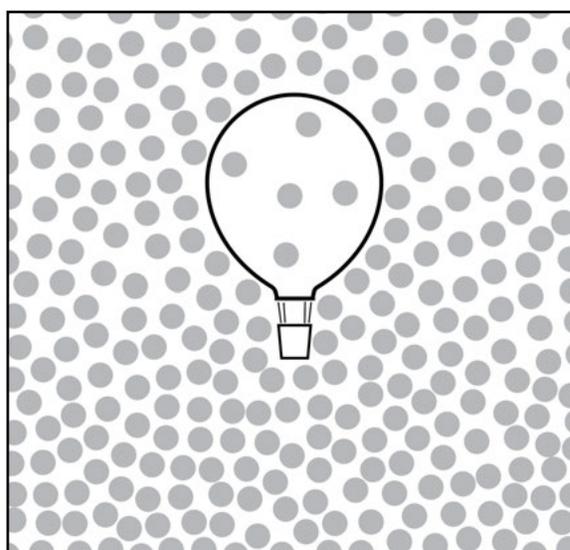
Remember, **density** is the ratio of mass to volume. So at a particulate level, the **density** of a substance is determined by two things: *how massive* the particles of the substance are, and *how closely packed or spread out* those particles are. These two aspects of **density** lead to two basic strategies for making lighter-than-air vehicles work.

Helium blimp



Helium-filled blimps and hot air balloons both float in the air by holding large volumes of low **density** gases. In a helium blimp, the gas is helium (He). At the same temperature and pressure as the surrounding air, helium has just as many atoms as the surrounding air has molecules. But the helium atoms are much less massive than the air molecules, so the helium is less dense.

Hot air balloon



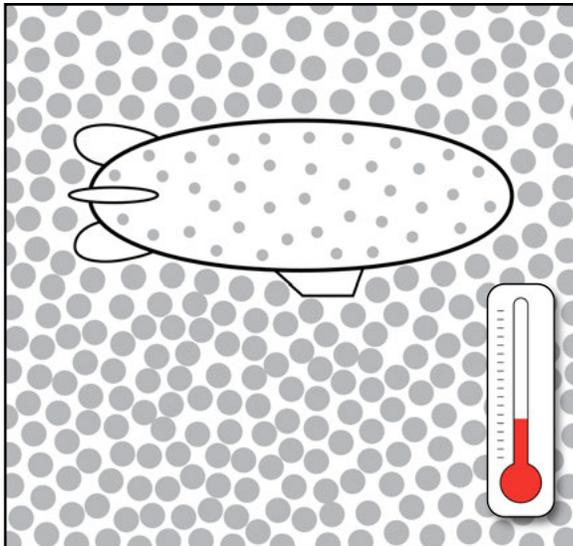
In a hot air balloon, the air inside the balloon has pretty much the same kinds of molecules as the surrounding air. Compared to helium atoms, the nitrogen molecules (N_2) and oxygen molecules (O_2) that make up most of the air both inside and outside the balloon are pretty massive. But the molecules of heated air move fast and spread out more. Many of them are pushed out of the opening at the bottom of the hot air balloon, leaving the hot air inside the balloon less dense than the surrounding air.

Density

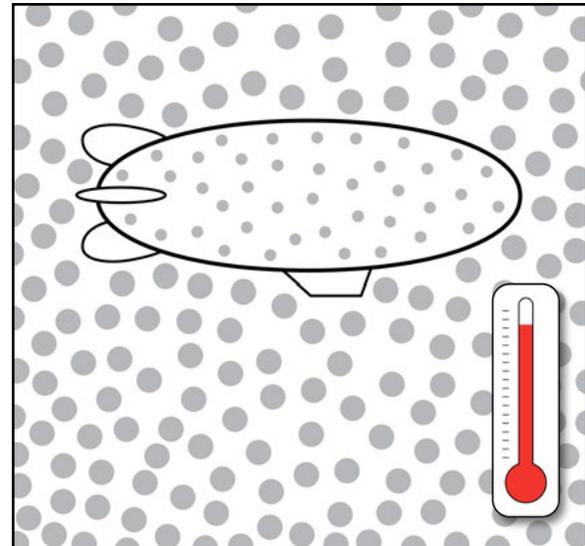
Floating in Air

It's not just what's inside the blimp or balloon that matters. The **density** of the air outside changes in different weather conditions. When the air is cold, it is denser because its molecules stay relatively close to each other. When the air heats up, its molecules move faster and spread out so that the air becomes less dense. Compare the two illustrations below. One shows the blimp in cooler, denser air, and the other shows the same blimp in warmer, less dense air.

Cooler, denser air



Warmer, less dense air



In both cases, the helium in the blimp is less dense than the surrounding air. But the blimp will rise more quickly and float more easily in one case than in the other. The air temperature might affect how much weight the blimp can lift—how many passengers or how much cargo it can carry.

 **TURN, TALK, AND WRITE**

Do you think the blimp can carry more weight in cooler air or warmer air? Explain.

Who's afraid of mixtures and density?

THE THREE LITTLE CHEMISTS AND THE BIG BAD WOLF

Once upon a time there were three little chemists who feared they would be eaten by the Big Bad Wolf. So they decided to move their laboratory out of the muddy end of the barnyard and into someplace safer.

“Let’s build a high security laboratory,” said Professor Bacon.

“What’ll we make it out of?” asked Dr. Swineberg.

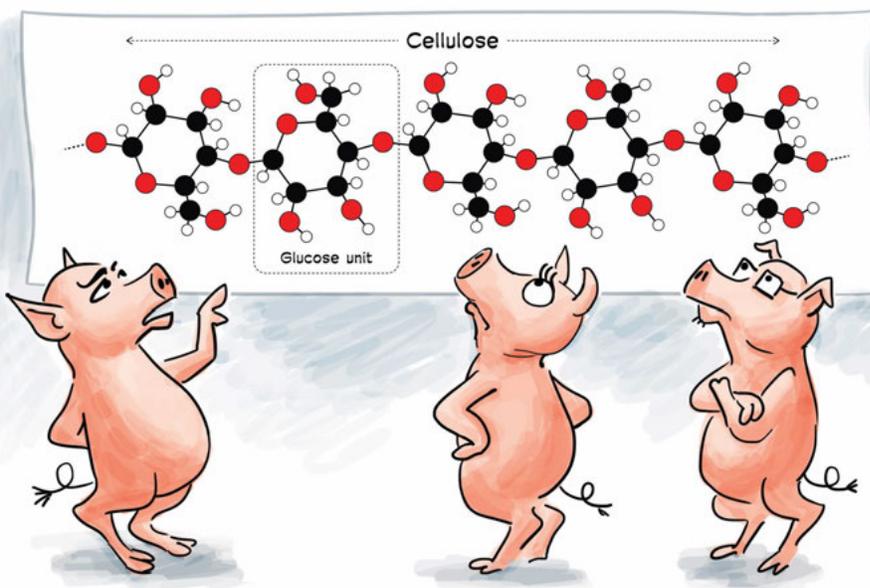
“Well,” said Professor Bacon, “how about straw?”

“Sure,” agreed Dr. Swineberg, shrugging her shoulders. “What could go wrong?”

“An intriguing suggestion,” said Mr. Spork. “As an agricultural by-product from the growing of grain, straw should be plentiful around the farm. Straw is made of the dried, discarded stems of grain plants. More precisely, it is made mostly of cellulose, which is a long molecule made of many glucose molecules joined together. Glucose, of course, is a sugar molecule that plants produce through photosynthesis. It is made of carbon, hydrogen, and oxygen.”

“Um... that’s great, Spork,” said Professor Bacon. “But enough chit-chat. We need to get the new lab built pronto, before the Big Bad Wolf comes and eats us.”

Well, you know what happened, right? The Big Bad Wolf came along, and he huffed, and he puffed, and he blew the three little chemists’ straw laboratory down! The three little chemists had to scramble to escape with their lives (and with their bunsen burners, test tubes, beakers, and other lab equipment).



Who's afraid of mixtures and density?

We interrupt this
pig tale with



When the Big Bad Wolf blew the straw lab down, was that a physical change or a chemical change? Explain. (Hint: Does the cellulose in the straw need to be transformed into another compound in order for the pieces of straw to separate from each other?)

“What a complete fail,” said Professor Bacon. “We need to choose a more high-strength material for our next lab.”

“Let’s make it out of sticks,” suggested Dr. Swineberg, waving her hoof at a nearby area of small trees.

“Interesting,” said Mr. Spork. “Wood is composed largely of lignin. As with the cellulose in straw and other herbaceous plants, lignin is made of carbon, oxygen, and hydrogen. But lignin molecules are structured differently, and form networks with much greater rigidity, giving woody plants their characteristic strength.”

“Spork,” said Professor Bacon, “I can hardly understand a word you say, but let’s get cracking on our wooden lab. I have a feeling that wolf will be along any minute.”

Sure enough, the three little chemists had no sooner set up their new laboratory made of sticks than along came the Big Bad Wolf. “Yum, I smell ham,” he thought to himself. And out loud he said, “Little chemists, little chemists, let me come in!”

But Professor Bacon answered, “Not by the hair of our chinny-chin-chins!”

Mr. Spork said, “Now are you going to huff and puff and blow our lab in?”

“Don’t give him any ideas,” hissed Dr. Swineberg.

But the Big Bad Wolf shook his head. “No,” he said. “My asthma is acting up. I’m all huffed and puffed out after that last straw house of yours I blew down.”

“It was a straw laboratory, not a house,” Professor Bacon corrected him.

“Whatever,” said the Big Bad Wolf. “I think I’ll just burn you out this time. I’ve got some matches here somewhere...” So the Big Bad Wolf scratched his match and he burned the wooden lab down. Again the three little chemists fled, barely able to keep ahead of the wolf while they gathered up their glassware and safety goggles, their x-ray crystallography machine, the paperwork for their National Science Foundation grant proposals, and all their other stuff.

We interrupt this
pig tale with



Was the burning of the wooden lab a physical or a chemical change? Explain.



“Back to the old drawing board,” said Professor Bacon. “We need to build our next lab out of something strong that won’t burn.”

“How about bricks?” said Dr. Swineberg. “Somehow I feel like it should have been bricks all along.”

“A brick laboratory would be a logical solution to our problem,” agreed Mr. Spork. “And bricks are a fascinating material, from a chemical point of view.”

“Oh, please stop him...” muttered Professor Bacon.

But Mr. Spork continued: “Bricks are made mostly of a combination of sand and clay, formed into blocks and then fired in an extremely hot

Who's afraid of mixtures and density?

kiln until the different compounds stick together in a hard solid. Sand is made of silica, which is a compound of oxygen and silicon. Sand makes up at least half the mass of brick. Clay makes up a large part of the remaining mass. The clay in bricks is typically made of extremely fine particles of aluminum oxide (AlO₃). In addition, bricks contain lime—”

“Wait, lime? Like lemon and lime?” said Professor Bacon.

“No,” said Dr. Swineberg. “Lime is the name for a group of materials high in calcium.”

“Correct,” said Mr. Spork. “The higher the calcium content of brick, the more yellow or white the bricks will appear. On the other hand, a high iron oxide content tends to give bricks a more pink color.”

“Oh, by all means, let's use pink bricks,” said Professor Bacon. “Much prettier. Only for heaven's sake, let's hurry and get this thing built, before the Big Bad Wolf eats us!”

We interrupt this pig tale with



Is brick a pure substance or a mixture? Explain.

Well, you might be thinking that the brick lab was wolf-proof, and that the three little chemists lived happily ever after and patented all kinds of discoveries and got rich off of licensing fees, or all got university jobs with benefits like free parking and seats at the 50-yard line for the annual big game, or whatever it is little chemists want. But not so. To make a long story short, the Big Bad Wolf took a hydraulic jack hammer to their brick walls and the whole building came crumbling down.



We interrupt this pig tale with



Is breaking bricks apart with a jack hammer a physical change or a chemical change? Explain.

“On the run again!” grumbled Dr. Swineberg, as she scurried along carrying a box of filter papers, tongs, binders full of lab notes, and a couple of laptop computers. “Will it ever end?”

“Now what?” grunted Professor Bacon when they finally stopped running.

“Yeah, what's left to try?” said Dr. Swineberg. “That wolf is a tough customer. So big and so bad!”

“Wicker,” said Mr. Spork.

“What? Wicker? Like wicker basket?” said Dr. Swineberg. “Isn't that going backwards? Wicker is just weak, flammable plant fiber woven into baskets and light-weight furniture.”

“Wicker is, like, halfway between straw and sticks,” agreed Professor Bacon.

Who's afraid of mixtures and density?

“Wicker,” insisted Mr. Spork, and he told them his plan.

The next day, the Big Bad Wolf set off following his nose in search of ham, as usual. He really had a thing for ham. Pretty soon he saw a sight that made him lick his chops. Up on a hilltop, the three little chemists had built a new laboratory entirely out of rattan wicker. “Ha!” laughed the Big Bad Wolf. “Do they seriously think wicker will save them? That’ll happen when pigs fly. I’ll be able to blow that down without any trouble.” (His asthma was better.)

In the wicker lab on top of the hill, Dr. Swineberg was on wolf watch. She saw the wolf coming, checked once with binoculars to make sure it was him and not the mailman, and turned to her colleagues. “He’s coming,” she said. “The Big Bad Wolf, not the mailman.”

“Time to go,” said Professor Ham.

“Make it so,” said Mr. Spork, taking a seat in a large wicker captain’s chair and fastening his seat belt.

“Aye-aye, Mr. Spork,” said Professor Ham, turning a valve on a nearby propane cylinder so that a jet of flame shot upwards from a jumbo quad burner above their heads. The giant, pink envelope of a hot air balloon quickly inflated above the wicker lab, which began to creak and quiver on top of the hill.

“Casting off!” shouted Dr. Swineberg, untying several ropes that held the wicker structure to the ground, and before the Big Bad Wolf’s astonished eyes, the entire laboratory, with its cargo of lab equipment and delicious chemists, rose gracefully into the air.

“How is that possible?” cried the wolf. “That whole contraption must weigh a ton!”

“Even so, it all has less mass than the cooler air displaced by the balloon,” explained Mr. Spork. But his voice was lost in the wind, leaving the confused, hungry wolf dancing with anger on the ground, unenlightened about density and the process of lighter-than-air travel.



We conclude this pig tale with

a **Question**

Is the burning of the propane fuel a chemical reaction or a physical change? Is the expansion of the air in the balloon a chemical reaction or a physical change? Explain.

In your own words, how does the hot air balloon float?

Writing

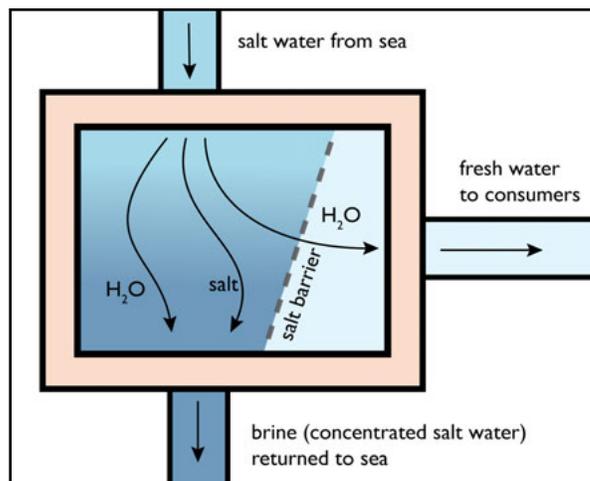
Water Shortage Solutions

Fresh water (water without salt) is a precious, life-giving resource, and in many parts of the world it's in terribly short supply. Desalination—removing the salt from seawater—may be a great **solution** to the problem of scarce fresh water. But for desalination to work on a large scale without causing environmental damage, people need to **concentrate** on the **concentration** of salt **solutions**!

Earlier we talked about getting the salt out of seawater through distillation: Water evaporates from salt water, and then the water vapor condenses into liquid fresh water. Most large-scale desalination facilities now use a different process called “reverse osmosis.” Basically this involves taking seawater and forcing some of it through a filter that will let water molecules through, but not salt particles.

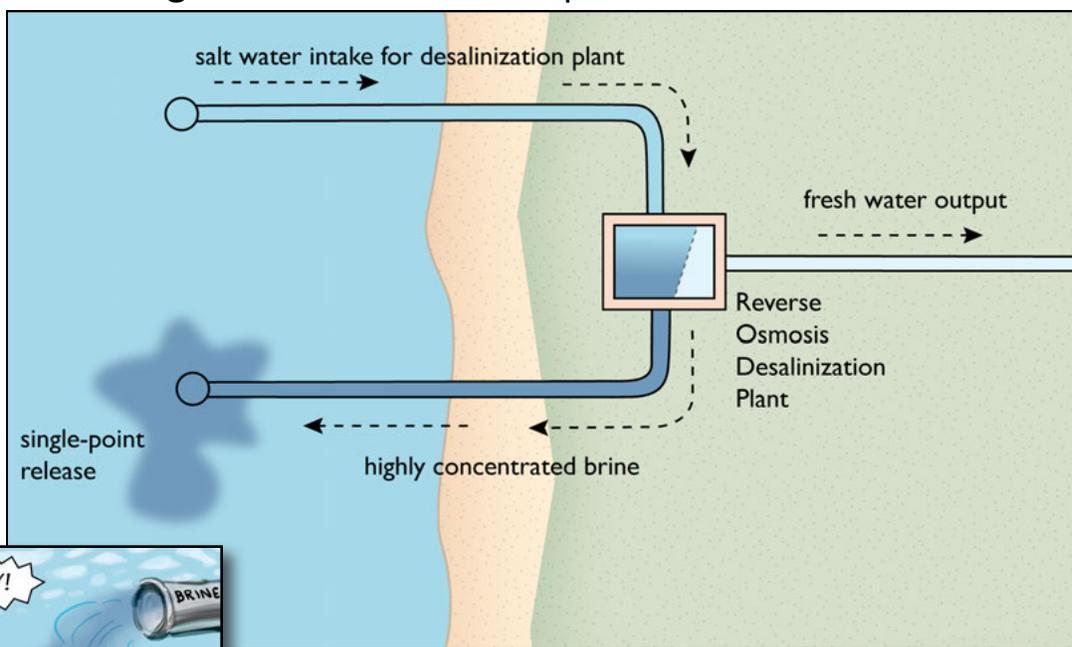
As fresh water is removed and sent to consumers to drink, irrigate farms, and so on, the **concentration** of the remaining saltwater mixture goes up. Highly **concentrated** salt water is called “brine.” Brine from desalination facilities is generally returned to the sea.

This waste brine discharge from a desalination plant can cause problems. The extra-high **concentration** of salt can sometimes be too much even for plants and animals that live in the sea!



Schematic illustration of the reverse osmosis process.

Plant Diagram #1: desalination plant alone



Note: These illustrations visualize higher **concentrations** of salt in the water as darker, even though salt water and fresh water don't actually look that different.

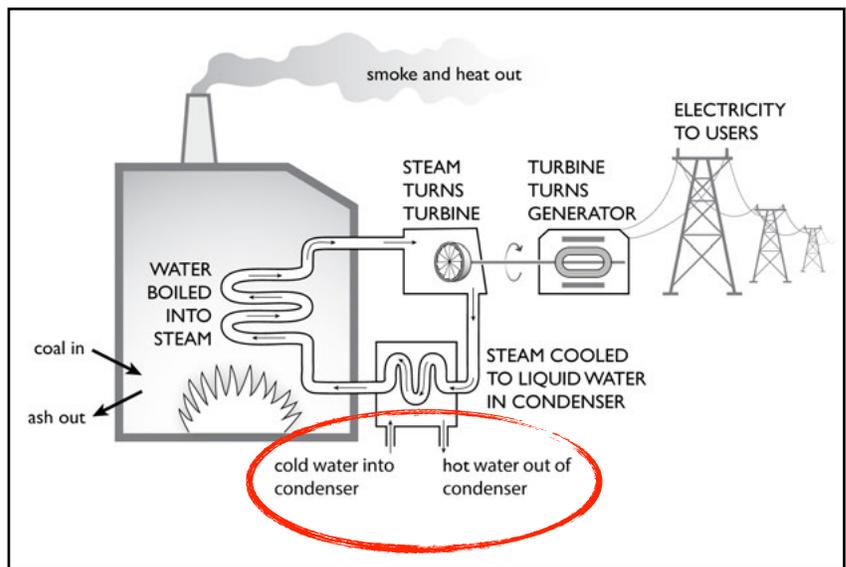
Writing

Water Shortage Solutions

How can you get fresh water out of seawater without hurting sea creatures that are sensitive to super-high salt **concentrations**? One method is to combine desalinization plants with power plants in a way that **dilutes** the brine before it is dumped back in the ocean. Before we look at how people combine power plants and desalinization plants, let's look at why some power plants use seawater.

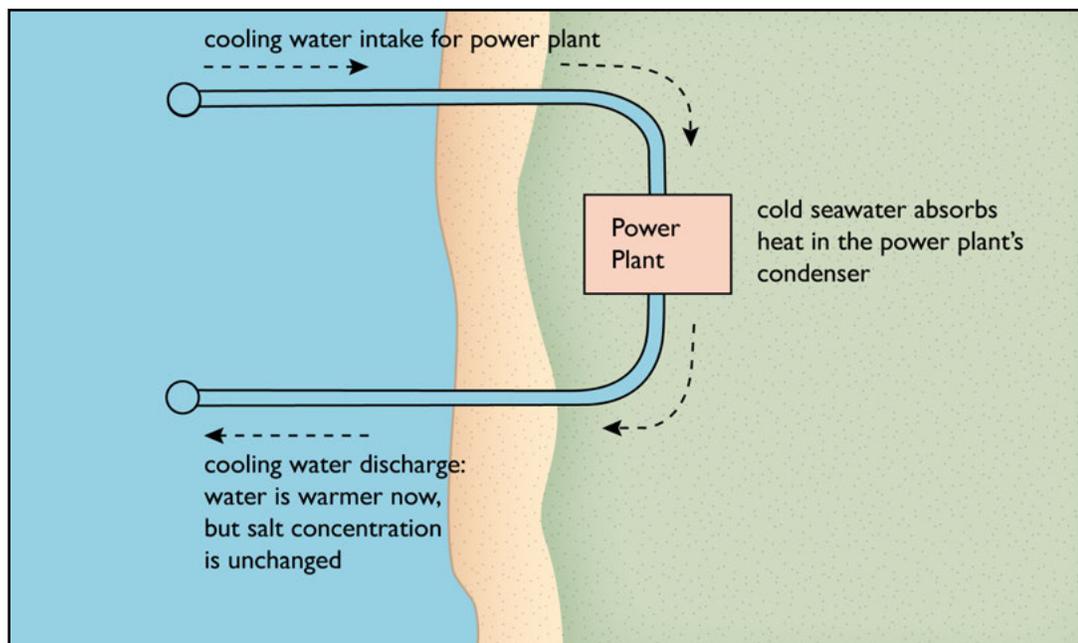
Many power plants generate electrical current using steam turbines. The steam that drives the turbines is part of a cycle: Fuel burns to boil water into steam; the steam turns the turbines; then the steam is cooled back into liquid water in a "condenser"; and that liquid water is reboiled to repeat the cycle. For power plants built near the ocean, cold seawater is often used in the condenser. The seawater is separate from the water that boils and turns the turbines. The seawater just absorbs heat in the condenser and carries it away. (Inland power plants typically use river water instead of seawater.)

To the **right** is a diagram of a coal-fired power plant. The part we're interested in right now is circled: That's where the seawater comes into the condenser, heats up, and then goes back out to the ocean.



Below is a diagram showing the intake and discharge of seawater for use in a power plant's condenser. The salt **concentration** of the seawater is not changed between intake and discharge.

Plant Diagram #2: power plant alone



Writing

Water Shortage Solutions

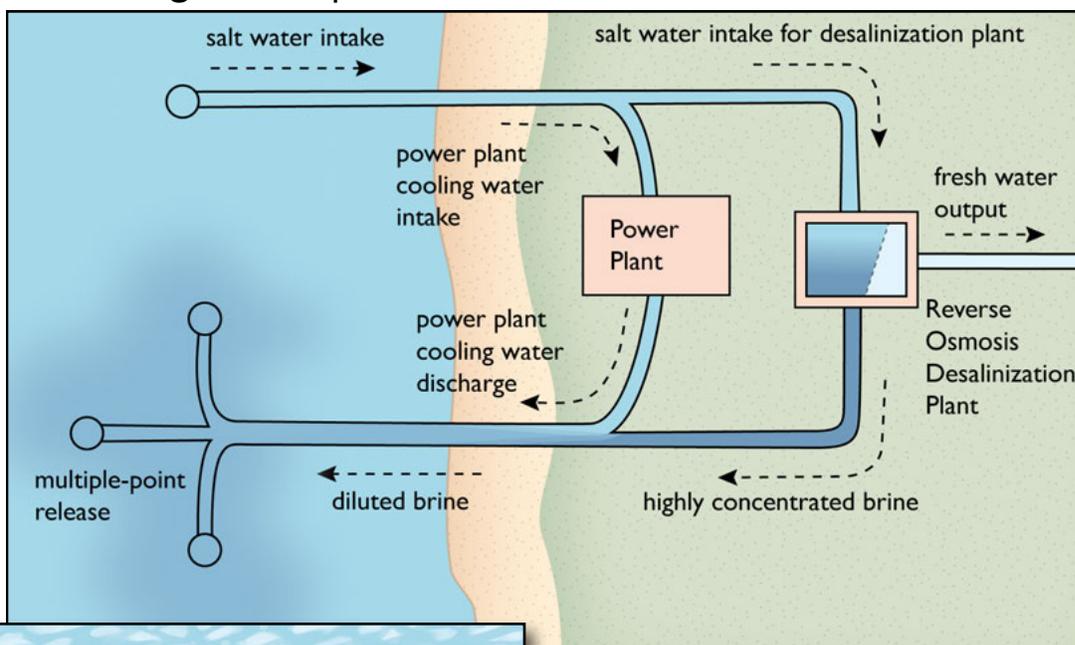
Okay, now we're ready to see how and why to put a desalination plant and a power plant together.

If you build a desalination plant near an existing power plant, the two facilities can share the same water intake and discharge pipes. That way, the seawater discharge from the power plant can **dilute** the highly **concentrated** brine discharged from the desalination plant.

Another way to **dilute** the brine discharge is to release smaller amounts of it at multiple points, instead of releasing it all in one place.

Plant Diagram #3 below shows a desalination plant that uses both of these techniques for **diluting** brine: sharing discharge pipes with a power plant and spreading the discharge out over multiple points. Compare the dark area that represents the **concentrated** salt water in this diagram with the dark area in Plant Diagram #1.

Plant Diagram #3: plants combined



Shorter, Please

In the play *Hamlet*, William Shakespeare has one of his characters say that “**brevity is the soul of wit.**” Brevity means briefness, shortness of duration. Wit, in Shakespeare’s time, meant intelligence, not just skill at making jokes. His phrase suggests that the best way to say something is often the briefest. Many writers and editors try to follow this ideal when revising prose. They boil down sentences to essential meaning, like chemists boiling seawater to get at the salt.

Making sentences clear and efficient takes effort, though. Maybe Shakespeare’s early drafts looked something like these:

- *The thing of which brevity is the soul is wit.*
- *Wit-wise, brevity seems to be the soul of it.*
- *If wit could be said to possess something in the nature of a soul, I would venture to suggest that, all things considered, its soul-like essence might consist in keeping what one has to say as much as possible on the short side, rather than wandering off into a maze of tortured syntax, or puffing up one’s discourse with florid and overblown diction, or being otherwise excessively and redundantly long-winded. Know what I mean?*



Thank goodness William was willing to revise!

“To be,” or not?

Often the verb *to be*, assisted by prepositional phrases, **dilutes** a sentence’s meaning. Underlining forms of *to be* (like *is* and *are*) and prepositions (like *by*, *in*, *of*, *to*, and *with*) can target your editing and help you strengthen a sentence. Is there a stronger verb than *is* or *are* that expresses the real action of the sentence? If so, use it!

Here’s an example:

Your meaning is **diluted** by extra words.

Underline any *to be* words and prepositions:

Your meaning is **diluted** by extra words.

The real action in this sentence hides in the passive construction “is **diluted**.” The real actor in the sentence is “extra words,” related to the passive verb “**diluted**” by the preposition “by.” Try this:

Extra words dilute your meaning.

continued on next page

Shorter, Please

Here's another example:

A sentence that is good can be likened to a solution that is concentrated.

This one contains three *to be* words and one preposition:

A sentence that is good can be likened to a solution that is concentrated.

Can we boil down all this being? "A sentence *that is* good" just means "a good sentence." "A **solution that is concentrated**" just means "a **concentrated solution**." "Can *be* likened *to*" could be replaced with "resembles," so that the whole thing becomes:

A good sentence resembles a concentrated solution.

We don't necessarily have to go that far. This is also okay:

A good sentence is like a concentrated solution.

After all, there's no law against using forms of *to be*, and "is like" works well for making a comparison. At least now it's a direct "is like" and not a **diluted** "can be likened to."

Your turn. Underline the forms of *to be* and any prepositions:

The thing I want is to keep it brief.

Now try revising it into a more direct, powerful sentence:

Here's another. Underline the forms of *to be* and any prepositions. Then revise the sentence:

The thing her poetry is expressive of is her feelings.

Now for something a little different. We can take a clear, **concentrated** sentence like "Adam enjoys visiting Aunt Lucy because she serves pink lemonade" and **dilute** it with *to be* words, prepositional phrases, and all sorts of unnecessary clutter. Here's an example of how to mess up a perfectly good sentence:

The reason for Adam's enjoyment of his visits with Aunt Lucy is the pink lemonade that is served by her during these visits.

Or, pushing it farther:

The real reason for Adam's tremendous enjoyment of his visits with dear Aunt Lucy is the fantastic pink lemonade that is so graciously served by her during these treasured visits.

Now it's your turn. You can make up your own clear, **concentrated** sentence to start with, or you can use the following: "Zena likes her lemonade less sweet than Adam likes his." Try to make it grammatically correct, but stylistically puffed up and silly:

Density

Density is the ratio of mass to volume. Put another way, **density** equals mass divided by volume. **Density** can be measured in grams per cubic centimeter (g/cm^3), or in other units of mass and volume.

The **density** of a substance doesn't depend on the size of an object made of that substance any more than the color of the substance does. For example, the four blocks of gold below all have different masses, and they all have different volumes. But they all have the same **density** (not to mention the same color):



What is the **density** of gold? To find out, divide the mass of each block by its volume:

$$9.65\text{g}/0.5\text{cm}^3 = \underline{\hspace{2cm}} \text{g}/\text{cm}^3$$

$$19.3\text{g}/\text{cm}^3 = \underline{\hspace{2cm}} \text{g}/\text{cm}^3$$

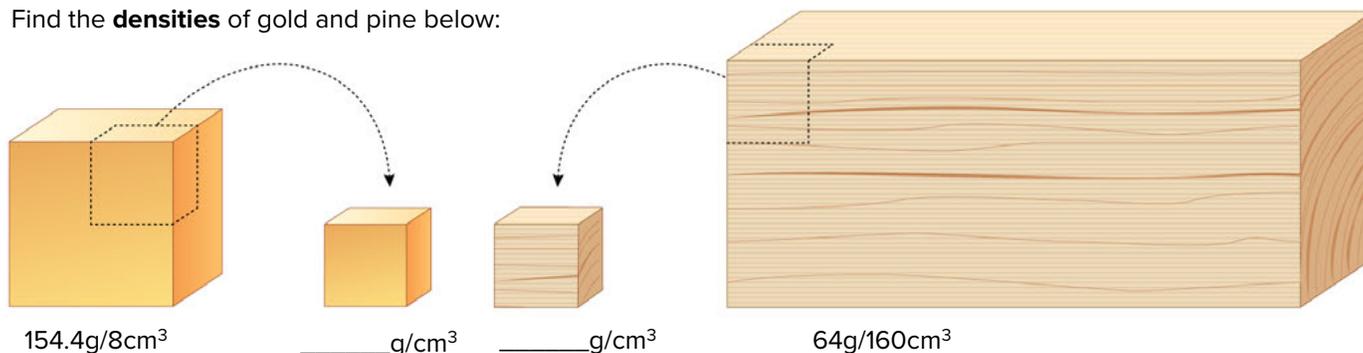
$$38.6\text{g}/2\text{cm}^3 = \underline{\hspace{2cm}} \text{g}/\text{cm}^3$$

$$154.4\text{g}/8\text{cm}^3 = \underline{\hspace{2cm}} \text{g}/\text{cm}^3$$

The second one, with no number in front of the cm^3 , might have seemed either pretty obvious or pretty tricky to you. When you just have a unit like cm^3 in an expression like $19.3\text{g}/\text{cm}^3$, it means **one** cm^3 (not zero cm^3 !). This expression shows the “unit rate,” which means it tells you how many grams there are per **one** cubic centimeter. That's what we use to describe the **density** of gold, and you can see by doing the math that it's the same for all four gold objects. They all have the same ratio of mass to volume.

Density helps us compare different substances—not just different *objects*, but the *substances* of which objects are made. Consider the block of gold on the left below, with a volume of 8cm^3 and a mass of 154.4g , and the block of pine wood on the right, with a volume of 160cm^3 and a mass of 64g . Just comparing the mass 154.4g to the mass 64g doesn't really get at the difference between these two substances, because the particular objects we're comparing are different sizes. But the **density** of the two substances tells us something essential about gold and pine wood, something that doesn't depend on the sizes of the objects. To compare the **density** of two materials, you consider pieces of each material with the same volume, and compare their masses. To do this without actually chopping pieces out of objects, you divide the mass of each object by its volume.

Find the **densities** of gold and pine below:



Density

Density plays a key role in determining whether objects will sink or float in **fluids**. Gold sinks in water because gold is denser than water, and pine floats in water because pine is less dense than water. In fact, the **densities** of different substances are often compared to that of liquid water.

density of gold > **density** of water > **density** of pine

 **TURN AND TALK**

With a partner, figure out how you would explain to a second grader why gold sinks and pine wood floats:

The Densities of Liquid and Solid Water

Ice floats in liquid water, so ice must be less dense than liquid water.

The liquid water in this glass has a volume of 55 cubic centimeters and a mass of 55 grams. The ice cube floating in the water has a volume of 9.5 cubic centimeters and a mass of 8.74 grams.



Find the **density** of liquid water:

$$55\text{g}/55\text{cm}^3 = \underline{\hspace{2cm}} \text{ g/cm}^3.$$

The answer to the above question is no coincidence. A gram was originally *defined* as the mass of one cubic centimeter of pure water!

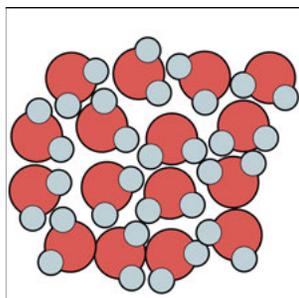
Now find the **density** of ice:

$$8.74\text{g}/9.5\text{cm}^3 = \underline{\hspace{2cm}} \text{ g/cm}^3$$

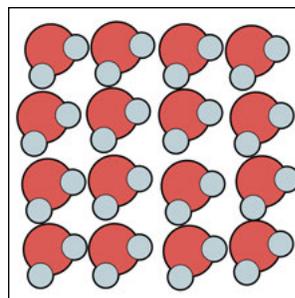
Ice is actually kind of a strange case. Usually, substances expand and become *less* dense when they are warmer, and shrink and become *more* dense when they are colder. Liquid water at room temperature, for example, is slightly more dense than hot water.

But when water freezes, it expands slightly and becomes less dense, as your calculation of the **density** of ice should show. Why? Well, when water molecules stop sliding past each other and form solid ice, they become organized in a way that actually spreads them apart slightly, so that there are fewer molecules per cubic centimeter. The white space in these illustrations represents empty space:

Liquid water



Ice



The History of Salt

“Please pass the salt.” An ordinary request that you might hear a couple of times when you sit down to a meal with family or friends, right? But the next time someone asks you to pass the salt, take a moment and consider this: Those little white grains inside your saltshaker represent a complex history that dates back to our earliest ancestors and spans our entire globe.

Sound like a trumped-up claim? How could simple table salt, which we take for granted, play such a significant role in human history? Well, for starters, humans and all other mammals need sodium chloride, or salt, as part of their diet. Sodium chloride is necessary for breathing and digestion. Without salt, mammals die.

Salt exists naturally in saltwater **solution** in the oceans and in underground springs, and in its solid **phase** in dry salt beds and in some rock. When early humans lived a nomadic life as hunters and gatherers, they got enough salt from the flesh of the wild animals that they ate. However, once people began to stay in one place and develop agriculture, salt became harder to get in their diet. In this new **phase** of social evolution, salt became an important and valued item. Farmers and the animals that they raised needed salt to survive. Farmers may have first domesticated wild animals by offering them salt.

Over time, farmers formed communities and engaged in trading and selling the food they produced. At some point, people discovered that salt could keep food from spoiling. Can you imagine how significant a discovery this was in a time before refrigeration? With the ability to preserve food came the freedom to travel far from home and benefit from a much wider market for trading and selling.

Salt became so valuable that in the ancient Roman empire, soldiers were often paid in salt. That’s why the Latin word for salt, “sal,” made its way into words like “salary” and “soldier.” To say that people are “worth their salt” means that they earn their pay.

A connection was forged between a rich supply of salt, a thriving trade, and power. According to Mark Kurlansky, the author of *The Story of Salt*, “On every continent, in every century, the dominant people were the ones who controlled the salt trade.” Today the United States is the largest producer of salt.



A goat licking a block of salt.



The Wieliczka salt mine in Poland.

In ancient China, rulers **concentrated** their power and wealth by keeping control of the production and sale of salt, raising prices whenever the government needed more money, despite the hardship it created for the citizens. In France, King Louis XIV taxed salt at such a high rate that some of his subjects began smuggling it at night to avoid paying the tax.

One of the most dramatic historical acts related to salt and power was carried out in 1930 by Mahatma Gandhi, an Indian leader. Yearning for independence from Britain’s rule, Gandhi chose salt as a symbol of British imperialism. Britain’s salt laws restricted India’s production of salt, requiring Indians to buy salt shipped from Britain. To protest the salt laws, Gandhi set off on a 240 mile walk to the Arabian Sea.

Examining the Focus Words Closely

SciGen Unit 8.5

 Scientific or  Everyday Use	 Definition	 Try using the word...
 phase noun	a state of matter, usually solid, liquid, or gas	What phase change takes place as snow melts?
 phase noun	a step in a process	What do parents mean when they say their child is “just going through a phase ”?
 homogeneous adjective	(of mixtures) even, smooth, the same in every part	Salt water contains evenly distributed sodium and chlorine atoms, making it a homogeneous mixture. Can you think of another?
 homogeneous adjective	even, undifferentiated	Is your taste in music homogeneous ? Explain.
 heterogeneous adjective	(of mixtures) uneven, lumpy, different in different parts	What foods do you eat that are heterogeneous mixtures?
 heterogeneous adjective	uneven, made up of different things	Is it good for a friend group to have heterogeneous interests? Why or why not?
 solution noun	a homogeneous mixture	Many people who wear contacts clean them with saline solution . Name a solution that you use in your daily life.
 solution noun	the answer to a problem	Describe a time when you came up with a solution to a big problem.
 dilute adjective	having a low amount of one substance dissolved in another	Which is more dilute , lemonade or tomato juice? How do you know?
 dilute adjective	weakened in force, effect, or presence	Think of a short story with a clear moral. If this story were longer and more complex, would the moral become dilute ? Why or why not?
 dilute verb	to lower the strength of a solution by adding water (or other solvent)	Can you think of a substance that you would dilute by adding something other than water?
 dilute verb	to weaken the force, effect, or presence of something, especially by adding something else	How do some people try to dilute the blame when they’ve done something wrong?
 density noun	the ratio of mass to volume	How do differences in density help balloons float in the air?
 density noun	the amount of something distributed in an area	Name some reasons that a city’s population density might increase.
 concentration noun	the rate of dissolved substance to solvent in a solution	As the water in salt water evaporates, what happens to the concentration of salt?
 concentration noun	mental focus, emphasis	What helps your concentration when you study?
 concentrated adjective	condensed in one area	When have you made a concentrated effort to improve your skills in a certain area? Did it work?

Examining the Focus Words Closely

SciGen Unit 8.5



Scientific or



Everyday Use



Definition



Try using the word...



fluid
noun

a substance that is in a liquid or gaseous phase

*Compare and contrast the characteristics of liquid and gaseous **fluids**.*



fluid
noun

a liquid

*Is it more important to eat healthy foods or drink enough **fluids** each day? Why?*



fluid
adjective

liquid or gaseous

*What causes a substance that is **fluid** to solidify?*



fluid
adjective

smooth, easily transitioning

*Which requires more **fluid** movements, dancing or playing sports? Explain.*