

Chapter 2:

The Care and Feeding of Matter



This is a photo of the Antennae galaxies, which are in the process of colliding. Both of these galaxies are made of matter. They probably also contain dark matter, but since nobody has any idea what that is, we don't discuss it in this chapter. Go ask an astrophysicist if you want more information about that.

2.1: Elements, compounds, and mixtures

Chemistry is the study of matter and how it turns from one substance to another. **Matter**, in case I didn't mention it before¹, is the same thing as saying "stuff." Or, in fancy science talk, matter is anything that has both mass and volume. Using this definition, we can see that a pancake is made of matter, but electricity is not.



This absolutely terrifying person is made of matter.

What does matter look like on a microscopic level?

You probably know that all matter is made of atoms. You also probably know that atoms are unbelievably small. Sometimes these atoms are bonded to each other to make molecules such as H₂O. You get the picture.

Elements are the different types of atoms that make up everything in the world. There aren't that many of them (118 at this writing), and each of them has a special symbol so you can tell them apart from the others. Examples of elements include gold, aluminum, and carbon.



The 24 carat gold plating on this 1981 GMC DeLorean is a good example of both an element and the lack of taste exhibited by "new money."

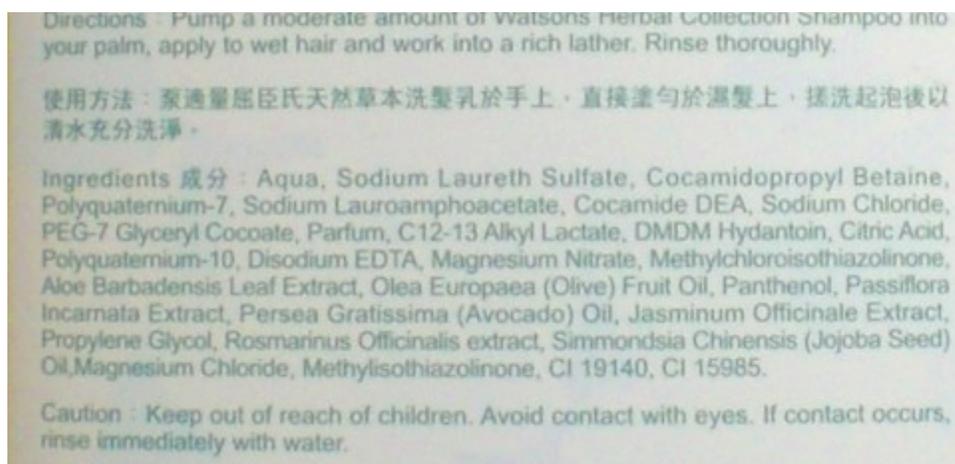
Compounds are the different type of molecules that make up everything in the world that aren't elements. Compounds contain at least two different types of atom, and frequently many, more. If you can write the chemical formula of something (such as CO₂ for carbon dioxide or C₆H₁₂O₆ for glucose), it's a chemical compound.

¹ I honestly forget.



The chemical compound in this glass, water, has been presented to you in an oddly formal way.

Mixtures are materials that contain more than one type of element or molecule in one place. Unlike elements or compounds, they don't have a single formula. For mixtures, you need lists like the ones on the back of shampoo bottles to tell you what's inside.



This shampoo is an example of a mixture. (Note: May cause rabies in infants.)

There are two different ways that you can make mixtures out of different materials, and they each have their own names:

- **Homogeneous mixtures** (also called solutions) occur when one thing (the solvent) dissolves another thing (the solute). A solution will always *look* as if it contains one thing, but there are at least two things dissolved together. Pee is an example of a solution.²
- **Heterogeneous mixtures** occur when two or more things are incompletely mixed with one another. Heterogeneous mixtures include oatmeal and ranch dressing.³

² Chapter 8 is all about solutions, so if you're too excited to wait, go check it out.

³ The "ranch" in ranch dressing refers to a dude ranch near Santa Barbara called "Hidden Valley Ranch." The original ranch was sold in the 1970's, and the salad dressing company was sold to Clorox in 1973. *Bon Appetit!*

Types of heterogeneous mixtures

- **Suspensions** are heterogeneous mixtures in which the little particles of stuff eventually settle out over time (just as the dirt in mud eventually settles).
- **Colloids** are heterogeneous mixtures in which the particles never settle, as in milk. Though colloids look homogeneous, they are cloudy in appearance, while solutions are not. There are also different types of colloids, but that's more than you probably want to remember



These beams of light are a sign that the smoke in this building is a colloid. Or that God is looking in the window.

2.2: Chemical and Physical Properties

As I child I learned that rocks are hard when a neighbor kid threw one at me. I ran home crying and now have a crippling fear of gravel. One of the properties of that rock was that it was hard.

Properties are the characteristics of a material that can be scientifically measured and studied. If you were to look around you and name one thing about each of the things in your room, those words you'd use would be the properties of each object.

Chemical Properties and Changes

Chemical properties are properties that describe the ability of a material to turn into another, different material. Put another way, it describes the ability of something to undergo a **chemical change**. Examples of chemical properties include:

- **Flammability:** The flammability of a material is the ability of that material to burn. Pieces of paper are said to be flammable, while rocks are not.

Describing chemical properties

As I mentioned literally right above this table, "flammability" is a general chemical property. However, if I were to ask you a chemical property of a piece of wood, "flammability" would be wrong. Instead, you'd have to say "it's flammable" to indicate whether it's flammable or not.



The Blarney stone isn't flammable, but is kissable.

- **Corrosion resistance:** Corrosion occurs when something is chemically broken down by reactions with its environment. The most common instance of corrosion is rusting, so a chemical property of iron is that “it rusts.”
- **Decomposition:** Any time a material breaks into smaller ones, it is said to have decomposed. This can be anything from the slow decomposition of dead bodies to the explosive decomposition of TNT. Depending on what's decomposing, the chemical property might be “it rots” or “it explodes.”

Other Chemical Properties

Any chemical change has a corresponding chemical property that goes with it. The examples above are general chemical properties, but chemical properties can be as specific as “can react with sodium to form sodium hydroxide and hydrogen gas.”

Though it's impossible to say whether a chemical change has occurred without performing an analysis of the material, there are several clues that can be used to tip you off that a chemical reaction has occurred:

- **It bubbles:** If you mix two things together and it starts to bubble, this is a good sign that a gaseous chemical compound has been formed through a chemical reaction.
- **It gets hot or cold:** Chemical reactions often absorb energy (get cold) or release energy (get hot). If either thing happens, you might have a chemical reaction.⁴



This building is undergoing a chemical change.

- **It changes color:** Not just a different color, but a *completely* different color. For example, if you mix something red with something white and the result is pink, it's not really a color change. However, if it turns green, that indicates a chemical change.
- **It forms a solid:** If two liquids are mixed together and a solid forms (this will usually make the liquid look milky), this is good evidence that two dissolved things have combined to form something that doesn't dissolve. This solid is called a **precipitate**.

⁴ One exception to this includes dissolving stuff. Though a physical change (the things present are chemically the same), the process of dissolving can either result in the resulting solution heating up or cooling down.

Physical Properties and Changes

Physical properties are properties that describe everything about a material except its ability to undergo a chemical reaction. Put another way, physical properties tell you the characteristics of something, but don't concern the actual chemical makeup of whatever you're talking about. Likewise, **physical changes** are changes in something that don't affect what something is actually made of.

The following are examples of the physical properties that an object may have:

- **Size/shape characteristics:** The size of something doesn't depend on what it's made of – it depends on how much stuff is present. Because of this, properties like length, width, height, and mass are physical properties.
- **Electrical conductivity:** Electrical conductivity is the ability of something to transmit electrical charge. If something is electrically conductive, don't jam it into an electrical socket unless it belongs there.



This whimsical light up display required electricity to work. It also caused a huge bomb scare in 2007.

- **Thermal conductivity:** Some materials conduct heat better than others. That's why coffee cups are made out of Styrofoam and not steel – because Styrofoam is better at holding in heat.
- **Malleability and ductility:** The malleability of a material is its ability to bend, and its ductility is its ability to stretch. Metals are both malleable and ductile (which makes it easy to make cables out of them) while wood is neither (which is why you don't see wooden cables very often).
- **Melting and boiling point:** The melting and boiling points of a substance are the temperatures at which it melts and boils, respectively. Though you might think that melting and boiling are chemical changes rather than physical changes, consider an ice cube. Ice cubes themselves are made out of water, and when you melt them you end up with the same material – water.

- **Solubility:** Solubility is the measure of how well one thing can dissolve in another.⁵ Again, you might have guessed that dissolving is a chemical change, which makes sense based on how it looks. However, if you taste both salt as a powder and salt water, you can tell that both have the same flavor because the salt is unchanged when it dissolves.
- **Hardness:** Some things are harder than others. That's why you can scratch glass dishes with diamonds but not with a tennis ball. This is also why hitting somebody over the head with a piece of foam rubber hurts a lot less than hitting them with a rock.
- **Density:** The density of a material is a measure of how much mass you can cram into a particular volume. Balsa wood floats because it has a density much less than that of water, while iron has a higher density than water and sinks.⁶ The equation for finding the density of a substance is:

$$\text{density} = \frac{\text{mass of an object}}{\text{volume of the object}}$$



Ships made of steel, like the one shown here, float poorly in water when poked full of holes.

Why in the world would I ever care about chemical and physical properties and changes?

- **You can use them to figure out what something is:** If you've got a big block of something gold-colored, you may assume it's gold. However, if you pick it up and it's incredibly light, it's probably something else. Though density is sometimes used to figure out what something is, more common physical properties include melting/boiling points and how something interacts with light.
- **It can keep you from blowing yourself up:** Sodium metal is pretty boring to look at – it's kind of a dull grey color and looks like it was left out in the rain for a while. However, if you weren't familiar with the chemical property that it explodes in water, you might be

⁵ In the case of basic science courses, we're usually talking about how well stuff dissolves in water. Also, I want to remind you again that Chapter 8 is all about solutions, if you're interested in reading more.

⁶ The density of water is 1.00 g/cm³ while that of balsa wood is 0.16 g/cm³ and iron is 7.87 g/cm³.

in for a bad time. For obvious reasons, it's important that we know whether something is flammable, poisonous, or otherwise generally deadly.

- **You can figure out the right material for a job:** If I want to build a laser, it's much more effective for me to use something that actually causes the formation of a laser beam. Nd-YAG is a good choice, while cheddar cheese is not. Likewise, if you wanted to build a skyscraper, steel would be a much better choice than gingerbread.



But nowhere near as tasty.

- **It helps you figure out how to separate mixtures:** If I want to remove the dirt from mud, it's good to know that dirt doesn't dissolve in water so I can just filter it out. However, if I were to attempt this same method to separate water from alcohol in the lab, it wouldn't work at all because they can't be filtered. By knowing the properties of various materials, you can figure out how to best work with them.

Distillation: Not just for moonshiners

Distillation is a process by which a mixture of liquids is heated. When heated, the component with the lowest boiling point will vaporize first and can be collected. This process is very useful if you're trying to purify chemicals, or if you're a hillbilly who wants to make moonshine.



The Dukes of Hazzard is about two brothers who drive around in a racist car.⁷

⁷ A 2015 Washington Post poll showed that Americans were evenly-split on whether the Confederate battle flag was a racist symbol. This leads to a difficult question: Even if many people who are not racist display the flag, does the flag's popularity among racists make this symbol racist anyway? Yes. Yes it does.

The Main Ideas in Chapter 2:

- Elements contain one type of atom, compounds contain one type of molecules, and mixtures contain a bunch of different things.
- Chemical properties describe the ability of materials to undergo chemical reactions, while physical properties describe non-chemical processes.
- It's important to know about chemical and physical properties because it allows you to work with the material most effectively.

Image credits:

- **Terrifying clown or whatever:** By Alex Proimos from Sydney, Australia (What a Jester!) [CC BY 2.0 (<http://creativecommons.org/licenses/by/2.0>)], via Wikimedia Commons. Clowns have traditionally been thought of as troublemakers - it was only for a time in the mid 20th century that they were thought of as purely kids' entertainers.
- **Gold-plated DeLorean:** By The original uploader was Lvtalon at English Wikipedia Later versions were uploaded by Chisholm4 at en.wikipedia. (Transferred from en.wikipedia to Commons.) [GFDL (<http://www.gnu.org/copyleft/fdl.html>) or CC-BY-SA-3.0. (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons. Plans are currently in the works to make "new" DeLoreans from old stock parts, though it's far from clear that this will ever happen.
- **A nice, cool glass of water:** By Jean Fortunet (Own work) [CC BY 1.0 (<http://creativecommons.org/licenses/by/1.0>)], via Wikimedia Commons. The old saying that you should drink eight 8-ounce glasses of water a day is kinda sorta based in reality. Actually, you need 13 glasses of water, but the water content in food counts toward that. Usually, that eight ounces is what you'll need to drink when moisture from the food is taken into account.
- **Shampoo label:** By Meadohsum (Own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0>)], via Wikimedia Commons
- **Train station with cool light beams:** Jack Delano [Public domain], via Wikimedia Commons. This beam effect (which you might remember from every horror movie ever made) is called the Tyndall effect after incredible scientific bad-ass John Tyndall (1820-1893).
- **Blarney stone:** By Brian Rosner [CC BY 2.0 (<http://creativecommons.org/licenses/by/2.0>)], via Wikimedia Commons. Kissing the Blarney stone is, by legend, supposed to give the kisser the gift of gab (i.e. eloquent speech). I don't know about that, but every time somebody I know gets back from Ireland, they can't shut up about having kissed it.
- **Building on fire:** By Sylvain Pedneault (Own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0>)], via Wikimedia Commons. Clearly, the brick isn't burning, but the inside parts are. Think of it as the creamy filling of the building, except that it's flaming and made of wood.
- **Mooninite giving the finger:** By Rekha Murthy [CC BY-SA 2.0 (<http://creativecommons.org/licenses/by-sa/2.0>)], via Wikimedia Commons. Several signs like this were posted in Boston to promote the 2007 film *Aqua Teen Hunger Force Colon Movie Film For Theaters*, resulting in panic. There were similar signs posted in nine other cities, but Boston was the only place where people freaked out.
- **Sunken ship:** By U.S. Navy [Public Domain], via Wikimedia Commons. This ship is the *Admiral Graf Spee* of the German *Kriegsmarine*. After sinking nine British ships in 1939, it was destroyed by its captain to ensure it didn't fall into British hands.
- **Gingerbread mausoleum:** By Cikola (Own work) [CC BY 3.0 (<http://creativecommons.org/licenses/by/3.0>)], via Wikimedia Commons. Yep, somebody actually made a mausoleum out of gingerbread.
- **General Lee:** By Valder137 [CC BY 2.0 (<http://creativecommons.org/licenses/by/2.0>)], via Wikimedia Commons. In *The Dukes of Hazzard*, the family has given up their moonshine business. However, this show was based on the movie *Moonrunners*, which was just chock full of moonshining.