Chapter 3: Elements and Properties and Stuff

This NYPD police car is a prop from "The Fifth Element," a 1997 movie featuring Bruce Willis and Milla Jovovich. At the time the movie was made, there were only five elements known to science: copper, bismuth, iridium, praseodymium, and meitnerium.

Photo by Citron: http://commons.wikimedia.org/wiki/File:The_Fifth_Element.jpg

Chapter 3: Elements and Properties and Stuff

Have you ever wondered where the properties of various materials come from? Have you ever thought about the vast cosmic miracle that is our universe, and wondered how all of the laws fit together to give us a finely-tuned and functioning world?

Neither have I. Anyway, here's a bunch of random stuff about elements and properties and stuff like that.

Section 3.1: Properties

When dealing with various compounds, it's handy to know what their properties are. After all, if they're really dense you probably want to hire somebody with a forklift to carry them. Or if they explode in air, you probably want to make somebody else haul them to the Dumpster. Either way, we should probably learn about the properties of matter.

Figure 3.1: *Some guy driving a forklift.*

http://commons.wikimedia.org/wiki/File:Doosan_forklift_in_June_2012.jpg

One way of describing properties are as either chemical or physical properties:

- **Chemical properties:** Properties that describe whether something will undergo some particular chemical reaction. For example, burning stuff is a chemical reaction, so "flammability" is a chemical property. Keep in mind that these chemical properties are always described as being present or not present, depending on the item. For example, a chemical property of a puppy is that it's flammable, while a chemical property of a tuba is that it's not flammable.
- **Physical properties:** These are basically any other properties. Melting point is, for example, a physical property, because it's not describing a chemical change. Other physical properties include density, color, and mass.

Mini Lab

Here's a simple experiment you can do at home: Using a match, test to see which items in your house are flammable and which are not. Record your data and share them with the fire department.

Another way of describing properties is as either intensive or extensive properties:

- **Intensive properties:** These don't depend on the amount of material present. For example, no matter how much ice you have, it will still melt at zero degrees Celsius. Other intensive properties include density, melting point, and solubility. Also, all chemical properties are intensive properties.[1]
- **Extensive properties**: These depend on how much stuff you've got. These include height, length, width, and mass.[2]

Section 3.2: States of matter

There are four states of matter that you're likely to bump into.[3] Here they are:

- **Solids** are the hard state of matter. If you hit yourself on the head with something and it hurts, it's probably a solid. Solids are hard because the particles that make it up are all stuck in place.
- **Liquids** are the wet state of matter. If you put your hand in something and it gets all wet, it's probably a liquid. The particles in a liquid stick together a little bit, but not so much that you can't swirl your hand around in it.
- **Gases** are the state of matter that you can't really see but floats around all over the place. The particles in a gas don't really hang around each other much, so they fly all over the place. Examples of gases include oxygen and flatulence.
- **Plasmas** are gases that have lost their electrons. You can commonly see these in fluorescent lights or by staring directly into the sun.

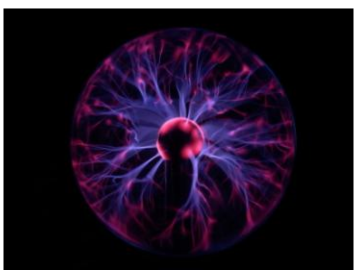

Figure 3.2: *This annoying toy is chock full o' plasma.*

http://commons.wikimedia.org/wiki/File:Plasma-lamp.jpg

[1] Why? Consider this: If you have a small drop of gasoline or a big bottle of gasoline, both will catch fire when you put a match to them. Though the amount of fire may be different, the basic tendency to burn is the same.
[2] Depending on what material you're talking about, "color" may be either an intensive or extensive property.
[3] There are other phases of matter that have recently been discovered by theoretical physicists. However, they're not very common and you're never going to see them, so don't worry about them.

Section 3.3: Chemical and physical changes

Sometimes it's handy to make things change.[4] These changes are either called chemical or physical changes:

- **Chemical changes** are when you change one substance into another by making or breaking chemical bonds. You can usually tell this is happening because a solid is formed when you mix two solutions[5], because the material gives off heat (is exothermic), because the material absorbs heat (is endothermic), because the color changes, or because the material bubbles.[6] Additionally, the chemical and physical properties of the material will change.
- **Physical changes** occur when you just change the form of something. For example, if you boil water, it's still H_2O, making phase changes physical changes. Other physical changes include breaking, stabbing, and dissolving.

Section 3.4: The Law of Conservation of Mass[7]

Way back in the 18th century, a guy named Antoine Lavoisier came up with the **law of conservation of mass**, which says that the products of a chemical reaction will weigh the same as the reactants. There's a lot of other historical stuff, but the important thing is the law of conservation of mass.[8]

Figure 3.2: *Antoine Lavoisier was the guy who discovered the law of conservation of mass. Unfortunately, his continued efforts to come up with a good haircut were unsuccessful during his lifetime.*

http://commons.wikimedia.org/wiki/File:Lavoisier.jpg

[4] It's not likely, however, that you'll get your crazy girlfriend or boyfriend to change.
[5] This solid is called a precipitate.
[6] Don't get this mixed up with boiling. When you think of a chemical change that results in bubbling, think of how Alka-Seltzer bubbles in water. Clearly, this is different than boiling.
[7] Though the law of conservation of mass doesn't really fit well into this section, it'
[8] Incidentally, this was kind of a new idea at the time. After all, if you burn a piece of wood, the weight of the stuff you make is a lot less than the weight of the stuff you started with. It wasn't until they could capture all of the gases and other stuff that was formed that Lavoisier could come up with the law of conservation of mass.

Section 3.5: Mixtures

Many times, matter gets all mixed up. **Mixtures** are what we call these mixtures.

- **Heterogeneous mixtures** are mixtures where the stuff in it isn't completely uniform. Usually, you can see a bunch of different things crammed together, as is the case with heterogeneous mixtures such as Chex Mix, granite, or a headless puppy.

- **Homogeneous mixtures** (also known as **solutions**) are mixtures in which things have mixed in a completely uniform fashion. Salt water, Kool Aid, and pee are all examples of homogeneous mixtures.[9]

> ***Do it at home!***
>
> Homogeneous mixtures are generally harder to separate than heterogeneous mixtures. As a demonstration you can do at home, separate the components of a heterogeneous mixture (granite) and a homogeneous mixture (air). Report back to your teacher on the difficulty of each.

There are a variety of different methods that we can use to separate the elements of a mixture. These include:[10]

- **Filtering:** This is what happens when you make coffee.

- **Distillation**: This is when you boil a mixture and one of the components vaporizes before the other. This is how vodka is made.[11]

- **Crystallization:** This is when you get a solid to crystallize from a solution, using a variety of different means. I can't actually think of any good examples where this is done outside of a lab, so use your imagination.

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[9] Air is another example of a solution, in which all of the components are gases. Similarly, metallic alloys are solid solutions.

[10] Chromatography is often described as a way of separating mixtures. However, chromatography isn't used to pull large quantities of mixtures – instead, it's used to identify the different elements of a mixture.

[11] Don't do this at home. Not only is it illegal, but it's also a bad idea given the flammability of ethanol. This was just an *example* of a distillation, not an instruction to go do something stupid.

Section 3.6: Elements and Compounds

You've heard of elements and compounds, so let's talk about 'em.

- An **element** is a pure substance that contains only one type of atom. For example, if I steal a 24 kt gold necklace from the jewelry store, all of the atoms in that necklace are the same as each other.

- A **compound** a pure substance that contains only one type of molecule.[12] Molecules, in turn, consist of a bunch of atoms bonded to each other. Common examples of compounds include NaCl (salt), sugar, and heroin. Compounds differ from elements in that they can be broken down back into their constituent elements using various chemical reactions.

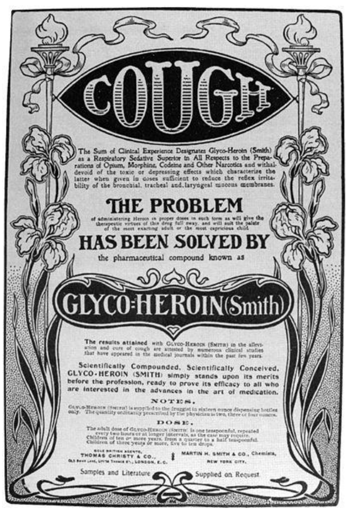

Figure 3.3: *In the late 19th and early 20th century, heroin was used in various patent medicines, including this one that was intended as a cough suppressant. Though we now think of the people of this era as being a bunch of drug-addicted idiots, codeine is nowadays used for the same purpose, despite its similarity (both chemically and pharmacologically) to heroin.*

http://commons.wikimedia.org/wiki/File:Heroin-Werbung.jpg

Section 3.7: The Law of Definite Composition

It used to be thought that salt had different formulas if you made it in different ways. This was, of course, because each method introduced its own impurities, which made it seem slightly different from other versions of the compound. **The law of definite composition** refuted this idea, stating that no matter how you make a compound, it's got the same formula.

[12] For ionic compounds, these are actually referred to as formula units because they don't form molecules. The basic idea, however, is the same.

Section 3.8: The Law of Multiple Proportions

Textbooks make this law sound super hard, when really it's not that challenging. When you get through the complicated terms, **the law of multiple proportions** basically says that if you've got a chemical formula, the number of atoms in the formula will be a whole number. As a result, chemical formulas look like H_2O and not $H_{2.1}O$.[13]

Chapter Summary

- Properties are either defined as chemical or physical, and intrinsic or extrinsic.
- Those annoying desk balls that light up when you touch them are full of plasma.
- To commit the perfect crime, you may need to perform a physical change (the crime itself) and a chemical change (to cover up the evidence).
- The law of conservation of mass states that the weight of the stuff you make is the same as the weight of what you started with.
- There are lots of types of mixtures and lots of ways to separate them.
- Heroin is a chemical compound.
- It's easy to get the law of definite composition and the law of multiple proportions mixed up, so be careful about that.

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[13] As written, the law of multiple proportions refers to ratios of masses of elements and so forth. This original explanation reflects the way in which the original experiments were performed. Since we're probably not going to perform those experiments again, we don't really need to worry about the specifics.