Stop Faking It!

Finally Understanding Science So You Can Teach It

Chemistry Basics

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Contents

Preface

The book you have in your hands is the eighth in the *Stop Faking It!* series. The previous seven books have been well received, mainly because they stick to the principles outlined below. All across the country, teachers, parents, and home-schoolers are faced with helping other people understand subjects—science and math—that they don't really understand themselves. When I speak of understanding, I'm not talking about what rules and formulas to apply when, but rather knowing the meaning behind all the rules, formulas, and procedures. I know that it is possible for science and math to make sense at a deep level—deep enough that you can teach it to others with confidence and comfort.

Why do science and math have such a bad reputation as being so difficult? What makes them so difficult to understand? Well, my contention is that science and math are *not* difficult to understand. It's just that from kindergarten through graduate school, we present the material *way* too fast and at too abstract a level. To truly understand science and math, you need *time* to wrap your mind around the concepts. However, very little science and math instruction allows that necessary time. Unless you have the knack for understanding abstract ideas in a quick presentation, you can quickly fall behind as the material flies over your head. Unfortunately, the solution many people use to keep from falling behind is to *memorize* the material. Memorizing your way through the material is a sure-fire way to feel uncomfortable when it comes time to teach the material to others. You have a difficult time answering questions that aren't stated explicitly in the textbook, you feel inadequate, and let's face it—it just isn't any fun!

So, how do you go about *understanding* science and math? You could pick up a high school or college science textbook and do your best to plow through the ideas, but that can get discouraging quickly. You could plunk down a few bucks and take an introductory college course, but you might be smack in the middle of a too-much-material-too-fast situation. Chances are, also, that the undergraduate credit you would earn wouldn't do the tiniest thing to help you on your teaching pay scale. Elementary and middle school textbooks generally include brief explanations of the concepts, but the emphasis is definitely on the word *brief*, and the number of errors in those explanations is higher than it

should be. Finally, you can pick up one or fifty "resource" books that contain many cool classroom activities but also include too brief, sometimes incorrect, and vocabulary-laden explanations.

Given the above situation, I decided to write a series of books that would solve many of these problems. Each book covers a relatively small area of science, and the presentation is slow, coherent, and hopefully funny in at least a few places. Typically, I spend a chapter or two covering material that might take up a paragraph or a page in a standard science book. My hope is that people will take it slow and digest, rather than memorize, the material.

This eighth book in the series is an introduction to chemistry basics, and the order and fashion in which I present the concepts is most likely different from what you have seen in other chemistry books. I spend quite a bit of time on the structure of the atom and why we believe that atoms look a certain way. I believe that you can't really understand chemical reactions without a thorough understanding of atomic structure. In addressing the structure of the atom, I include results from quantum mechanics. This might seem odd in a "basic" chemistry book. These results, however, are crucial to our understanding of the atom. Also, there are a number of simple ideas one can draw from quantum mechanics without getting into all sorts of messy math. So, no differential equations in this book! I am developing a follow-up chemistry book that goes into more depth in many areas of chemistry, so just for kicks I might toss in some of that messy math at that time.

There is an established method for helping people learn concepts, and that method is known as the Learning Cycle. Basically, it consists of having someone do a hands-on activity or two, or even just think about various questions or situations, followed by explanations based on those activities. By connecting new concepts to existing ideas, activities, or experiences, people tend to develop understanding (unlike with memorization). Each chapter in this book, then, is broken up into two kinds of sections. One kind of section is titled, "Things to do before you read the science stuff," and the other is titled, "The science stuff." If you actually do the things I ask prior to reading the science, I guarantee you'll have a more satisfying experience and a better chance of grasping the material. Keep in mind that the activities in this book are designed to help with *your* understanding of chemistry. Although you might decide to use some of the activities with students, that's not their main purpose.

It is important that you realize the book you have in your hands is *not* a textbook. It is, however, designed to help you "get " science at a level you never thought possible, and also to bring you to the point where tackling more traditional science resources won't be a terrifying, lump-in-your-throat, I-don't-think-I'll-survive experience.

One more thing. I often get comments from teachers something like the following: "But I don't teach quantum mechanics (or binary electric circuits,

or calculus, or whatever) in middle or elementary school. Why should I learn the basics of these subjects?" Once again, it's about comfort level. If you know more than you are required to teach, you have a better idea of how to approach classroom discussions and how to answer certain questions. In other words, you are in charge rather than the classroom materials being in charge.

Dedication

I dedicate this book to Norris Harms, who convinced me to quit working for other people and strike out on my own. It hasn't been easy, but it's been worth it. I also dedicate this book to Rob Warren, who taught me how to write directly and clearly and drop the scholarly sounding tone and flowery language.

About the Author

As the author of NSTA Press's *Stop Faking It!* series, Bill Robertson believes science can be both accessible and fun—if it's presented so that people can readily understand it. Robertson is a science education writer, reviews and edits science materials, and frequently conducts inservice teacher workshops as well as seminars at NSTA conferences. He has also taught physics and developed K–12 science curricula, teacher materials, and award-winning science kits. He earned a master's degree in physics from the University of Illinois and a PhD in science education from the University of Colorado.

About the Consultant

Michael Kralik received his PhD in chemistry from the University of Utah with post doctorate studies in chemistry, pharmacology, and toxicology. He has been faculty at the university and has conducted many faculty and staff development seminars. Kralik has established product development and manufacturing operations domestically and internationally, and has directed the development of hundreds of products for major corporations in chemical, medical, pharmaceutical, and electronics industries. He has developed K–12 science curricula, teacher inservice workshops, and many award-winning educational toys, games, and science kits.

About the Illustrator

The recently-out-of-debt, soon-to-be-famous, humorous illustrator Brian Diskin grew up outside of Chicago. He graduated from Northern Illinois University with a degree in commercial illustration, after which he taught himself cartooning. His art has appeared in many books, including *The Beerbellie Diet* and *How a*

Real Locomotive Works. You can also find his art in newspapers, on greeting cards, on T-shirts, and on refrigerators. At any given time he can be found teaching watercolors and cartooning, and hopefully working on his ever-expanding series of *Stop Faking It!* books. You can view his work at *www.briandiskin.com*.

About This Book

What you have before you is a book intended to help you understand many of the concepts basic to the study of chemistry. This is not a chemistry textbook, and it takes an approach that differs from that of most of the books on chemistry you'll find. For starters, this is a view of chemistry from someone (me) who has primarily a physics background. This means that I will take a "ground up" approach to the subject, beginning with what atoms look like and why we believe that atoms look that way. This does not follow the historical development of modern chemistry, but it's the approach that makes the most sense to me. I also will steer away from memorization whenever possible. I see no sense in memorizing the properties of various materials based on their position in the Periodic Table when you can rather get a clear picture of why materials do what they do based on an understanding of the mechanisms that underlie the patterns in the Periodic Table.

There will be a second book on chemistry in the *Stop Faking It!* series, so don't fret that there are a number of traditional concepts missing from this book. People might argue about what concepts are "basic" and therefore should be in this first book, but I just have to chalk that up to a difference of opinion.

I do make a few assumptions about what you already know before you pick up this book. For example, I assume you know that there are three states of matter—solids, liquids, and gases—and that you have a rough idea of the properties of each state of matter. I also assume you know that when you combine atoms together, the result is called a molecule. Other than that, I pretty much start from scratch.

All that said, here are the major ideas I hope you can grasp by the time you finish this book:

- What an element is, both historically and presently
- Our current view of what is inside an atom, and what electrons are or aren't doing inside an atom
- How energy is involved when physical systems, including atoms, are by themselves and how energy is involved when those systems get together

- The different ways, and different reasons, atoms bond with one another
- What we mean by a chemical equation, how to balance a chemical equation, and how we can get valuable information from a chemical equation. This includes why in the world someone would want to balance a chemical equation, other than to do another textbook chemistry problem.
- What we mean by organic chemistry, why it is a special branch of chemistry, and how it affects our lives

Warning. This book is intended as a resource book for teachers and parents, and not necessarily a book of activities designed for the classroom. The use of certain chemicals in the classroom is highly regulated in many areas, and I do not recommend doing the activities in this book with students without checking on the regulations in your particular area.

Safety Note

Though the activities in this volume don't require anything more volatile than household vinegar, safety should always be in the forefront of the mind of every teacher. (This is not intended as a book of classroom activities, by the way. Rather, the activities are designed to enhance your understanding of the subject before you get into the classroom.) Your individual school, or possibly the county school system of which your school is a part, likely has rules and procedures for classroom and laboratory safety.

You can also find specific guidelines for the safe storage, use, and disposal of thousands of types of chemical products in the Material Safety Data Sheets (MSDS). Start with *http://www.ilpi.com/msds/#Internet*. This site links to dozens of free searchable databases, including those of top American and European universities.

NSTA has also published several award-winning titles covering the safety theme at all school levels. For the elementary level, there's *Exploring Safely: A Guide for Elementary Teachers* and the *Safety in the Elementary Science Classroom* flipchart. Middle school-level offerings are *Inquiring Safely: A Guide for Middle School Teachers* and the *Safety in the Middle School Science Classroom* flipchart. Finally, there's *Investigating Safely: A Guide for High School Teachers*.

How can you avoid searching hundreds of science websites to locate the best sources of information on a given topic? SciLinks, created and maintained by the National Science Teachers Association (NSTA), has the answer.

In a SciLinked text, such as this one, you'll find a logo and keyword near a concept, a URL (*www.scilinks.org*), and a keyword code. Simply go to the SciLinks website, type in the code, and receive an annotated listing of as many as 15 web pages—all of which have gone through an extensive review process conducted by a team of science educators. SciLinks is your best source of pertinent, trustworthy internet links on subjects from astronomy to zoology.

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Chapter 1

Simple Models

As I said in "About This Book," I'm not going to take the usual approach to the subject of chemistry. Because virtually all explanations of chemical reactions are based on our current model of atoms and molecules, I figure the first thing to do is help you understand why we believe that atoms and molecules look and act the way they do. That's not a trivial issue, because despite the impression you might have gotten from textbooks, no one has ever seen an atom in the sense that you can see this page in front of you. What we have are observations and experiments that lead us to formulate models of atoms.

"Fire. Definitely 'Fire'..."

For starters, I'm going to have you experience a few chemical reactions and then present a model the early Greeks used to explain observations. That'll get us in the mood for making up models to explain the world around us.

Things to do before you read the science stuff

In this section, you'll need a few chemicals that you can get at the store—baking soda, vinegar, and Epsom salts. You'll also need a couple of metal bottle caps with the plastic inner liner removed, a ruler, a pencil, tongs, wooden matches, a candle, and a lighter. Ready to play? Good. Now, before you do anything, prepare to observe carefully. Pretend that your life depends on how detailed your observations are. Okay, that's too melodramatic, but observe carefully anyway, okay?

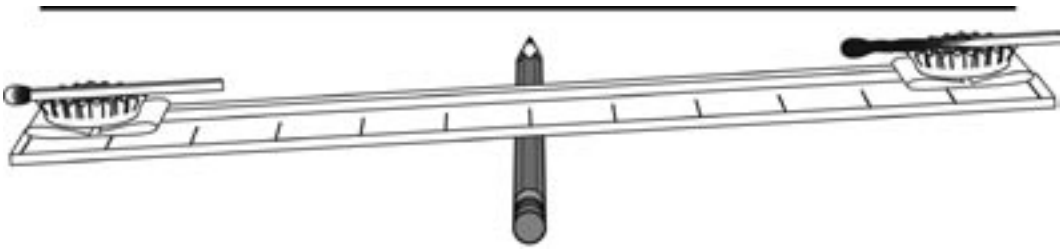
Pour a small amount of baking soda in a clear glass or plastic cup. With the cup sitting on a table, add maybe 40 milliliters (an ounce or two) of vinegar. Without disturbing the cup, describe what happens. What do you see and hear? Now light a candle and place it next to the cup. Carefully "pour" the contents of the cup onto the candle. "Pour" is in quotes because I don't want you to pour out any of the liquid in the cup. Just use a pouring motion until something happens to the candle. See Figure 1.1.

For the next couple of activities, a double pan balance is nice to have. If you don't have one, make one as follows. Get two bottle caps and use masking tape to secure them to opposite ends of a ruler. Then place the ruler on top of a pencil, with the pencil in the middle of the ruler, and adjust the positions of the bottle caps until this whole thing balances. See Figure 1.2.

Figure 1.1

Figure 1.2

Figure 1.3



Place one wooden match on top of each bottle cap (or in each pan if you have an actual double pan balance) and check that your apparatus still balances. Strike a third match and light one of the matches sitting on the ruler on fire. Make careful observations of the burning process. Which way is the flame directed? Does anything besides the flame seem to "leave" the match as it burns? What about after the one match completely burns? Does your apparatus stay in balance? If not, which way does it tip? (See Figure 1.3.)

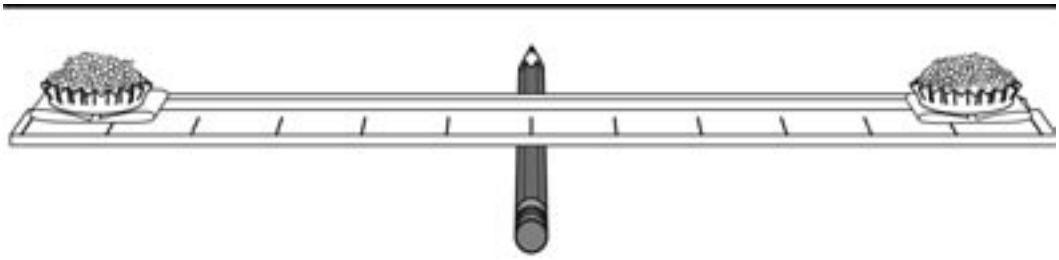
Get another match and a small glass. Light the match and hold the glass, inverted, above the match, as shown in Figure 1.4.

Figure 1.4

Before the match burns your fingers, blow it out. Then take a look at the inside of the glass. Rub your finger on the inside of the glass. Notice anything?

Clean out your bottle caps and get your balance in balance again. Pour a small pile of Epsom salts into each bottle cap, adjusting the amounts until your apparatus is in balance. If you're using a regular pan balance, you still need to use bottle caps for this part. Simply place the Epsom salts into bottle caps and then place the bottle caps on the balance pans. No masking tape necessary unless you're using a ruler for a balance. Check out Figure 1.5.

Figure 1.5



Next remove one of the bottle caps containing Epsom salts. Using tongs so you don't burn your little fingers, hold the bottle cap over a flame (either a

candle or a lighter) for a few minutes. Notice any change in the appearance of the Epsom salts. Notice anything else while you're heating things up?

Figure 1.6

After heating for a few minutes, let the bottle cap cool down a bit and then replace it on either your ruler or your double pan balance. Which way does the balance tip? What does that mean in terms of the relative weights of the two sides?

The science stuff

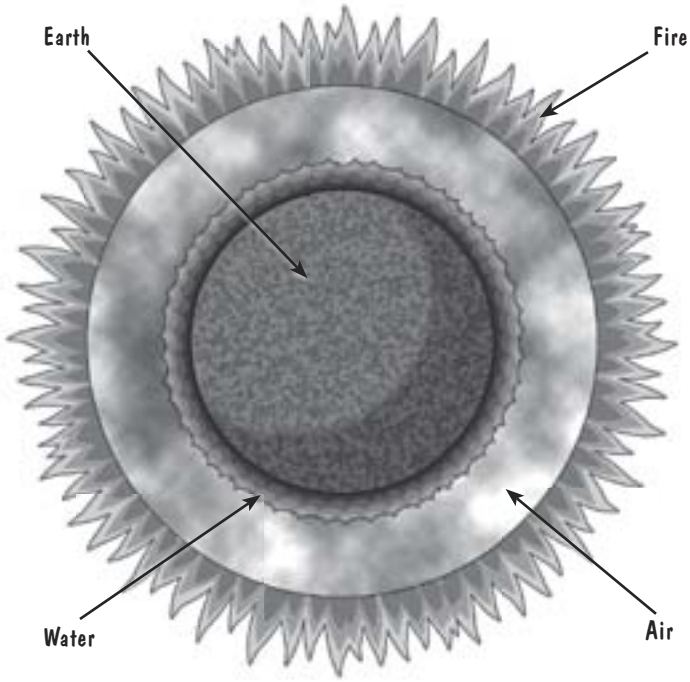
Before getting into explanations, see if your results agree with the following. As you do this, you no doubt will realize that, throughout this book, I'm going to be discussing what most likely happened in the "things to do" sections. Therefore, you can get through the book without ever doing a single activity other than reading. That, however, is not the best way to learn concepts. Actually experiencing things will give you a solid basis for understanding concepts, a better basis than you can get just by reading. Okay, end of lecture. Here's what you probably observed.

- Vinegar has a distinctive smell. Baking soda doesn't. When you combine the two, lots of fizzing and bubbles result. If you put your hand or cheek just above all the fizzing, you'll notice that *something* seems to be moving upward, because liquid keeps spitting at you.
- "Pouring" the baking soda and vinegar mix over the candle results in the flame being snuffed out. You can't see anything actually pouring over the candle.
- A burned match weighs less than an unburned match, as evidenced by the fact that your balance, be it ruler or actual pan balance, went down on the side of the unburned match. The flame of the match rises upward.
- When you hold a burning match underneath a small glass, a mist of water forms on the inside of the glass. You can usually see this, but you can always feel it when you rub your finger on the inside of the glass.
- When you heat Epsom salts, they sizzle quite a bit. You can definitely see some sort of liquid form as you heat the salts, and they change appearance from crystalline to something that's more of a powder. You should have found that Epsom salts lose weight when you heat them.

Okay, time to explain your observations. As promised in the introduction to this chapter, we'll use a model developed by a Greek philosopher, in particular one named Empedocles. His model was that all things in the universe consist of four elements: earth, water, air, and fire. These elements are characterized by the following qualities: earth is cold and dry, water is cold and moist, air is hot and moist, and fire is hot and dry. Empedocles went even further, assigning qualities such as love and hate to these elements, but we won't go into that other than to say that love and hate are emotions often associated with chemistry and other sciences.

According to Empedocles, each object or substance is some combination of the four elements. The elements themselves never exist in a pure form, although they aspire to take their proper place in the universe. The proper place for earth is, well, at the Earth. Because water floats on earth, its proper place is above the Earth. Air rises higher than water, so air is above the water. Fire rises highest of all (flames go upward, right?), so it's on top. Figure 1.7 shows how Empedocles might have viewed things.

Figure 1.7



You can explain lots of occurrences by assuming that things are composed of these elements. I'll attempt to do that for the activities you did in the previous section. No guarantees that my explanations are what Greek philosophers would have provided, but they're dead and can't do anything about it.[1]

[1] Irreverence aside, I want to be clear that I am not a qualified scientific historian. The explanations I'm going to provide are most assuredly not the ones Empedocles or other Greek philosophers would have provided (for one thing, mine are too simple), and of course there were many theories that competed with the one of earth, fire, air, and water. My only purpose here is to show that seemingly primitive models can go a long way toward explaining observations, even in the hands of a rank amateur like me.

So here goes my explanation of the activities assuming the Greek notion of there being four elements—earth, water, air, and fire. Let's start with baking soda and vinegar. The vinegar itself obviously has lots of water in it, but it must also contain air. If it didn't contain air, then the smell from the vinegar wouldn't be able to rise up to your nose. Keep in mind we're talking about air as one of the four basic elements. If there isn't any air or any fire, then nothing rises up. When you mix the two, you get more evidence of "trapped air." Those bubbles rise upward and release air. Most likely, the baking soda itself also contains the element air. The fact that you can "pour" an invisible substance out of the cup and extinguish a candle is a bit more difficult to explain, but not too hard. Clearly whatever is right above the mixture of baking soda and vinegar has air (because it's invisible) and either a bit of earth or water, or both. We know there is either earth or water present, because otherwise this stuff would move upward just like all other things that have lots of air. There's enough water and/or air, in fact, that this substance falls downward and extinguishes the candle. When the candle is extinguished, clearly that invisible falling substance has absorbed the fire in the candle.

Let's move on to a burning match. An unlit match contains earth (obviously) and also contains fire. You know it contains fire because simply striking the match releases the fire. The evidence that a match also contains water is in the formation of a fine mist of water on the inside of a glass held upside down over a burning match. Okay, why should a burned match weigh less than an unburned match? Well, you have released fire and water from the match, so there's less "stuff" in the match. Of course, it's not quite that simple. Because fire tends to move upward, you might expect the release of the "upward tendency" of the fire would actually cause the match to weigh more. However, we can get around that by noticing that water would contribute to the match's weight, so as long as you release more water than fire, the match will weigh less.

I'm going to leave the explanation of the Epsom salts to you. I'm sure you can do as well as I can simply by considering the release of some of the four elements that make up the Epsom salts. I *can* add one thing, which is that the salts go from a bright, crystalline substance to a powdery substance. The early Greeks associated light with fire, so as the crystals lose some of their luster, they are obviously losing fire.

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Time to move on to a different kind of simple model to explain observations. Another Greek philosopher by the name of Democritus was among the first to come up with the theory of atoms—small, indivisible things that make up all matter. In Democritus's view, and in the view of many scientists who also subscribed to the atomic theory into the eighteenth century, there are many kinds of atoms in the world. **Elements** are substances that are composed of only one kind of atom, and observations can be explained by the exchange

of atoms among substances. Contrary to the theory of Empedocles, who thought that "pure" elements did not exist in the real world, Democritus tells us it is now possible to have *pure* elements that are composed of only one kind of atom. Like the theory of Empedocles, however, explanations amount to figuring out how much of each element is contained in a substance, how much might be added, and how much might be subtracted. Let's take the heating of Epsom salts as an example. The Epsom salts lose weight when you heat them. Obviously that means that you have fewer atoms after heating than before heating. The liquid that forms during heating obviously indicates the release of some kind of water-like atom that was trapped in the salts prior to heating.

Although it might seem that the early atomic model of Democritus, being closer to what we believe today, is better than earth, air, fire, and water, it's actually not as good. At least with Empedocles' model you could figure out the properties things might have based on how much of each of the four elements they contained. Small, indivisible atoms don't even offer that much, especially if the known list of elements is rather small. Of course, the point of this chapter is not to convince you that early models were good ones. My main point is to illustrate, with a few examples, how people used models to try and explain real-world observations. We do the same thing today, even though our models are a bit more complicated.

More things to do before you read more science stuff

In order to introduce more complex models, I'm going to have you do a few more things. To start with, grab a balloon, blow it up, and tie it off. Then rub it on your hair and move it away from your hair. Unless you have a lot of gel or hairspray in your hair, or if you don't *have* much hair, your hair should move toward the balloon as you pull it away.

Now get an empty aluminum can and place it on a hard surface. Rub that balloon on your hair again and then slowly bring it near the can. What happens?

More science stuff

If you already know a bit about static electricity, you might have an explanation in hand for what you just observed. If you rely on Empedocles or Democritus for your explanation, though, you're going to have difficulty. Nothing in those models explains how one object can exert a force on another object without even touching it. You'd have to chalk it up to the influence of the gods, which of course would have worked just fine for the Greeks.

The kinds of interactions you observed have been known for a long time (since the eighteenth century), and they led to alterations of the model of the

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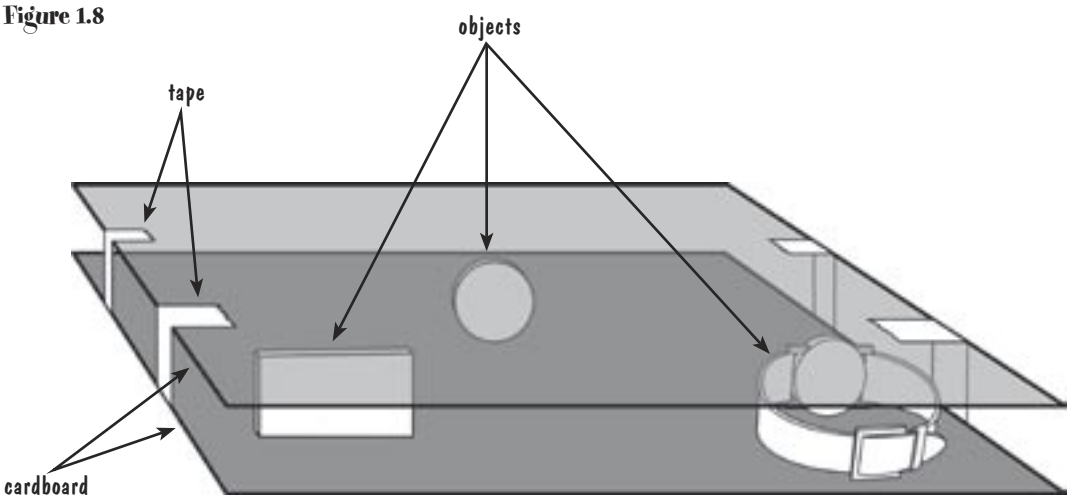
atom. Scientists proposed that there were two kinds of charges in the world—positive and negative. Positive charges repel positive charges, negative charges repel negative charges, and positive and negative charges attract. In other words, like charges repel each other and unlike charges attract each other. Normal atoms have an equal number of positive and negative charges, so usually atoms don't exert forces on one another. If you can somehow separate the charges, though, then you have either repulsive or attractive forces. If atoms are neutral, with equal numbers of positive and negative charges, then that explains why we don't see dramatic electric forces between atoms as an everyday occurrence. A neat solution, but then you have to figure out how those positive and negative charges are distributed in the atom. That leads us to the next section.

Caution: Do not use a "classroom demonstration" laser for the activity that follows. Anything stronger than a laser pen can be a danger to your eyes, and you should also be careful not to shine even a laser pen into anyone's eyes.

Even more things to do before you read more science stuff

For this section, you have a couple of alternatives. If you happen to have a laser pen or pointer, then you need that, a couple of sheets of cardboard, tape, and a few objects that are made of, at least in part, a reflective surface. A hand mirror will do, as will a watch with a glass front. If you don't have a laser pen,[2] you need

Figure 1.8



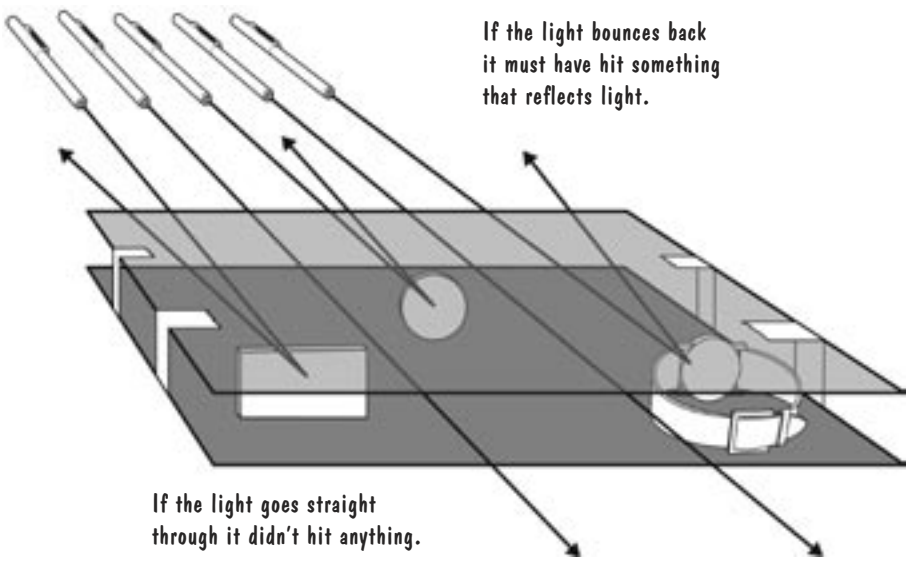
[2] In case you don't know, laser pens are relatively cheap, so you might want to go ahead and buy one. They're lots of fun to play with, and they're great for providing pets with exercise—just shine the pen on the floor or wall and watch as your pet chases the image all over the place.

a few marbles, the pieces of cardboard, the tape, and a few objects that are less breakable than a mirror or a watch.

In what follows, I'll describe what to do if you have a laser pen. After that, I'll explain how to adjust if you're using marbles instead of a laser pen. Take your mirror or watch and two pieces of cardboard, and arrange them as shown in Figure 1.8. Use tape to secure things as best as you can. This doesn't have to be a solid structure, but it should at least hold together for a while.

Now look from above and shine your laser pen in between the cardboard pieces from the side. By having a wall on one side of the apparatus or by placing a piece of paper on one side, you should be able to tell when the light shines straight through and when it bounces off something. With careful observation, you should be able to tell exactly where the light goes when it bounces off something. Take a look at Figure 1.9.

Figure 1.9



In this case, you know what's under the cardboard, so you can make sense of where the light goes. But what if you didn't know what was under the cardboard? Could you, with enough observations, get an idea of what was under the cardboard, or at least many of its features? Sure you could. It would take patience, but you could do it. To test that, have a friend tape a different object under the cardboard. Using just the laser and what happens to

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the laser when you shine it in from the side, see if you can guess what's hidden under the cardboard. Yes, this will take a bit of time.

For those without laser pens. If you don't have a laser pen, you're going to have to shine something else on the object under the cardboard, something like marbles. By throwing marbles from the side, you can get some idea of what might be under the cardboard. They'll bounce off of something hard or something that's elastic. They'll just move on through if they don't hit anything.

Of course, this is more difficult than using a laser pen, so if you can spring about ten bucks for a laser pen, do that.

Even more science stuff

SCILINKS. THE WORLD'S A CLICK AWAY

Topic: J. J. Thomson

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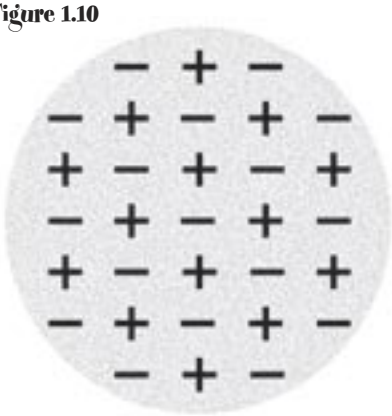
Code: CB004

Even though scientists figured out that there must be plus and minus charges in atoms,[3] they had no idea how those charges were arranged. One popular model was proposed by J.J. Thomson in the nineteenth century. He suggested that the positive and negative charges were evenly distributed around the atom, as shown in Figure 1.10.

Other models were proposed, and eventually people figured out a way to decide what might be inside an atom—shoot things at it! In an experiment that was a lot like what you did with your pen or marbles and the cardboard, a scientist named Ernest Rutherford did just that. He shot tiny things called alpha particles at a thin sheet of gold foil. Alpha particles have a positive charge, and if atoms look like Thomson's model, you would expect them to fly on through the gold foil, with maybe slight deflections when they get near the mixture of positive and negative charges in the gold atoms. Well, that's not what happened. Many alpha particles did go right on through, but some bounced straight back or nearly straight back, as if they had hit a brick wall. It was like a laser light hitting a piece of mirror or a marble hitting a solid object in the activity you did. Look at Figure 1.11 (p. 11).

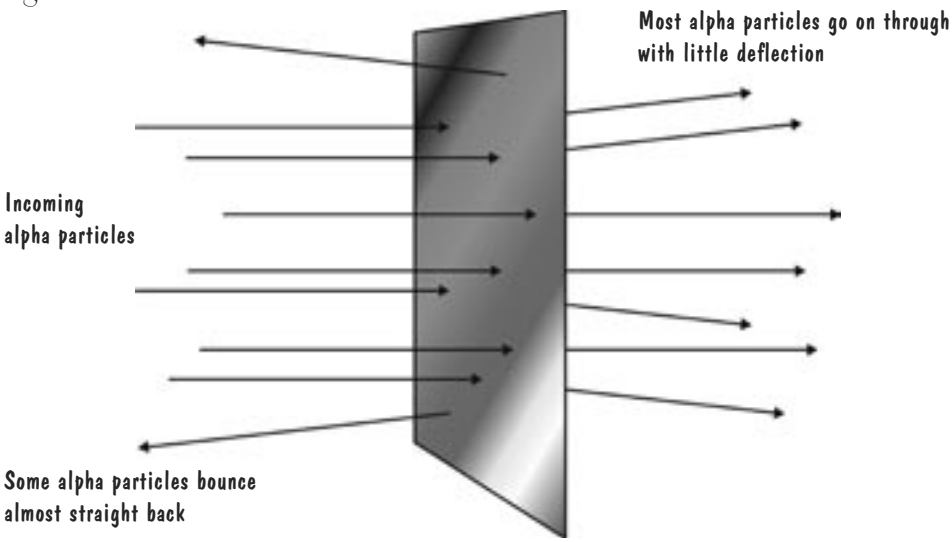
Figure 1.10



Thomson's model of the atom: evenly dispersed negative and positive charges.

[3] The labels of plus and minus are rather arbitrary. As explained in the *Stop Faking It!* book on electricity and magnetism, these might as well be called red and blue things that are inside atoms. It's all part of model building.

Figure 1.11



Rutherford Experiment

The only explanation Rutherford could come up with was that all of the positive charge in the gold atoms was concentrated somewhere in the atom. Only a high concentration of positive charge could repel the positively-charged alpha particles enough to send them back the way they came. He further reasoned that the concentrated positive charge had to be at the center of the atom. If it weren't, then the uneven distribution of concentrated positive charges would push on one another until they attained a symmetrical distribution, namely at the center of each atom. So, from Rutherford's time on, the accepted model of an atom was that there was a concentrated positive charge at the center, surrounded by negative charges in many other places around the atom, as shown in Figure 1.12 (p. 12). Later models would show that most of an atom is empty space, with neither positive nor negative charges. And for the record, we have a name for those negative charges in an atom—they're called **electrons**.

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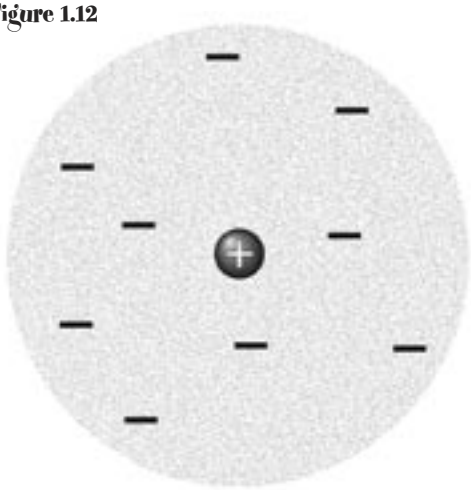
And even more things to do before you read even more science stuff

This is a pretty short section of the chapter. Here's a challenge for you. Assume that all matter is made up of atoms that have a positive charge at the center and a negative charge dispersed around it. Also assume that there are many kinds

Figure 1.12



A new model of the atom.

of atoms in the universe. Using this model, see if you can come up with explanations for the activities I had you do in the first part of this chapter (baking soda and vinegar, burning a match, etc.). Try to explain all your observations, including any weight loss that occurred. No fair using any chemistry you might already know. Just use the model of the atom I've given you.

And even more science stuff

This is an even shorter section of the chapter. All I want you to do is realize that you couldn't get very far in your explanations in the previous section. In fact, you might say that the theory of earth, fire, water, and air is still better at explaining things than a model of atoms that consists of positive charges at the center and negative charges surrounding them. Of course, we're going to refine our model of the atom in future chapters, so you can guess which model—the model of Empedocles or the atomic model—wins out in the end.

Chapter Summary

- The notion that the universe is composed of elements—substances that cannot be simplified—has been around for centuries.
- The early Greek philosophers proposed that the universe was composed of four basic elements—earth, water, air, and fire. This theory can be used to explain a large number of observations.
- Soon after the theory of four elements, other philosophers proposed that the universe is composed of indivisible objects called atoms, and that elements in the universe are composed of only one kind of atom.
- Early experiments with electricity led scientists to propose the existence of two kinds of electric charges—positive and negative. This idea became part of models of the atom.
- Rutherford's experiment demonstrated that atoms have a concentrated positive charge surrounded by a disperse negative charge.
- At the end of this chapter, we do not have a complete model of the atom.

Applications

1. In describing motion, the Greek philosopher Aristotle relied heavily on the four-element theory of Empedocles. With that theory, Aristotle didn't need gravity or friction to explain why things did what they did. Objects fell to Earth because they were made primarily of earth and sought their proper place in the universe, not because of some unseen force of gravity. Objects similarly came to rest when you moved them across a surface, not because of a force of friction, but because once again they assumed their proper place in the universe. Not a bad idea actually, because Einstein's theory of general relativity, which is the currently accepted theory of forces and motion in the universe, uses this idea.

2. Another early Greek philosopher named Lucretius used a primitive model of atoms to explain how we smell things. He proposed that substances gave off atoms of a particular size and shape. These atoms would enter the pores of the human body only if their size and shape matched the size and shape of the pores. Different pores in the nose accepted different atoms, and through this mechanism humans identified different smells. This proposed process is remarkably similar to our currently accepted theory of how people smell things. Instead of pores, we refer to different "receptor sites" in the nasal membrane that connect with different-shaped molecules. More on this in the Applications section of Chapter 6.

Glossary

activation energy. The input of energy required to cause a chemical reaction to take place.

air. One of the four elements proposed by Empedocles. Also, a gas that is composed primarily of nitrogen and oxygen molecules. Also, the stuff we breathe.

alpha particle. A helium nucleus that has been stripped of its electrons and therefore contains two protons and two neutrons. As such, alpha particles are positively charged. Also, the particle that all other particles look to for leadership (think dogs).

atom. A tiny thing that has a positively charged nucleus surrounded by negatively charged electrons. Elements are made up of only one kind of atom. Also, a tiny little guy who had his own comic book for a while.

atomic mass. A number, measured in atomic mass units, that when truncated gives the total number of protons and neutrons in the nucleus of a specific atom. This number is not an integer because of naturally occurring isotopes.

atomic number. A number that tells you the number of protons in a specific atom.

atomic weight. A term chemists used to use when they really meant atomic mass. You will still find this term in use today.

balanced equation. A chemical equation that has the same number of each type of atom on either side. Also, an equation that has its life together.

Bohr. A physicist who first proposed a model of the atom that included discrete energy levels for electrons.

catalyst. A chemical that helps a chemical reaction occur more easily or more rapidly, while not technically part of the reaction as a product or reactant.

chemical equation. An equation that isn't really an equation in the mathematical sense, that shows what reactants come together to produce certain products in a chemical reaction.

conductor. Something that conducts electricity well. Metals are good conductors. So are people who have the ability to get people where they need to go on a train.

covalent bond. A bond between atoms in which the atoms share one or more electrons.

cross-linking. The process in which a group of molecules connects a bunch of long-chain polymers. What you do to succeed in a game of Red Rover.

Democritus. A Greek philosopher who was one of the first to come up with a theory of atoms.

diffraction grating. A device that separates light out into its individual frequencies.

earth. One of the four elements proposed by Empedocles. When capitalized, it's the big round thing we live on.

electric force. A force between different charges.

electromagnetic wave. A wave that is composed of changing electric and magnetic fields. Radio waves, microwaves, light, and x-rays are all electromagnetic waves. Also, what electrons use for surfing.

electron. A tiny little particle that mathematically has no size at all, and is negatively charged. We usually find electrons attached to atoms.

electron shell. A somewhat diffuse location in an atom in which there is room for a specific number of electrons. Also, what electrons pull into when disturbed by goings on in current events.

electron shielding. The process by which outer electrons are shielded from the positive charge of the nucleus by electrons that are closer to the nucleus.

electronegativity. A number assigned to each kind of atom that gives an indication of how strongly the atom attracts electrons when bonding with other atoms. An electric current that gives off bad vibes.

element. A substance with specific properties that cannot be reduced to a more basic substance. Elements are composed of a single kind of atom. Also, a car designed for surfers.

Empedocles. A Greek philosopher who proposed that the universe is composed of four elements—earth, air, fire, and water. His theory does a remarkably good job of explaining a number of physical observations.

energy. A rather abstract concept that is important for understanding how electrons in atoms behave and for understanding various chemical reactions. Something you're supposed to get from those bad-tasting gel packets you get at fitness stores.

energy levels. A series of energy "slots" that are available to electrons in atoms, and which exist whether or not they contain electrons.

fire. One of the four elements proposed by Empedocles. Something Beavis likes to say.

frequency. How often something happens. With waves, it's a measure of how often the oscillations occur.

inert gas. the name given to elements at the far right column of the Periodic Table. These elements have complete outer electron shells, and therefore don't interact much with other elements. Hence, the label of inert.

inner shell. An electron shell that is relatively close to the nucleus compared with the electron shells that are farther away from the nucleus. Of course, there actually must be outer shells in the atom for ones close to the nucleus to be called inner shells.

insulator. A substance that does not conduct electricity very well.

ion. An atom that contains extra electrons or has lost one or more electrons, and is thus charged rather than neutral.

ionic bond. A bond between different atoms in which an electron moves from one atom to the other, resulting in an electric force between the atoms.

isotope. An atom that has one or more "extra" (more than the usual number) neutrons in its nucleus. The extra neutrons do not change the identity of the atom.

Law of conservation of mass. The law that states that no mass is gained or lost in a chemical reaction. This is technically not true, but the gain or loss of mass in chemical reactions is so small that it is usually ignored.

Lewis dot formula. A visual method of showing how many valence electrons are in an atom and how those valence electrons end up when bonds form.

mass. A measure of the inertia of something, or the amount of matter contained in something.

mass spectrometer. A device that can be used to measure the charge to mass ratio of charged particles.

metal. A classification of elements that conduct heat and electricity well, and also have other properties in common. Most of the elements in the Periodic Table are metals. Also, a type of music that takes getting used to for us old folks.

Millikan. A physicist whose experiment successfully determined the charge on an electron.

molecular formula. A combination of element symbols and subscripts that tells how many of each kind of atom contribute to a given molecule.

molecular mass. The mass, in atomic mass units, of one molecule of a substance.

molecular weight. The term chemists used to use instead of molecular mass, though it is still commonly used today.

monomer. The basic unit of a polymer.

neutral atom. An atom with an equal number of positive and negative charges.

neutron. A particle with no charge that is found in the nuclei of atoms and has approximately the same mass as a proton. Also, Jimmy's last name.

noble gas. Another name for an inert gas. Also, the gas of kings and queens.

nonmetal. An element that does not have the properties of metals. These elements often have inferiority complexes because they are defined by what they are not.

nonpolar covalent bond. A covalent bond in which the distribution of shared electrons is such that the overall molecule does not have a preferred direction of charge.

nucleus. The concentrated center of an atom that consists of protons and usually neutrons. The base structure of the word *nuclear*. Note that there is no "u" between the c and the l in *nuclear*.

orbital. The name given to the probability distribution associated with various electron energies in atoms.

organic chemistry. The branch of chemistry that deals with the myriad of molecules that contain carbon. Also, chemistry done without pesticides.

oscillation. Any periodic variation in time.

outer shell. An electron shell that is farthest away from the nucleus in an atom.

Pauli exclusion principle. A principle that states that no two electrons in an atom can have exactly the same set of quantum numbers.

Periodic Table. A large table that contains all of the elements and illustrates a number of patterns relating to the structure of atoms and the properties of elements. Also, the card table that comes out on holiday dinners when you need an extra place for the kids to sit.

photosynthesis. The chemical process by which plants convert solar energy to food.

polar covalent bond. A covalent bond in which the distribution of shared electrons results in an asymmetric charge distribution.

polymer. A molecule that consists of repeated basic units. Many mers.

probability distribution. A visual representation of the probability of finding something in various places. An especially useful tool in determining what electrons in atoms are doing.

product. One of the molecules that results from a chemical reaction. Something you need if you're going to make money on eBay.

proton. A positively charged particle found in the nucleus of every atom.

quantum mechanics. A mathematically based theory in physics that does a great job of explaining how things behave on an atomic level. Also, a group of people who are trained in repairing quanta (bad joke I learned in college).

quantum number. A number that describes various energy levels in atoms.

reactant. One of the molecules that serve as the beginning point for a chemical reaction. Reactants go on the left in a chemical equation.

Rutherford. A physicist who conducted an experiment that showed there was a concentrated positive charge in atoms. Also, Lumpy's last name.

sea of electrons. An expression that describes how valence electrons behave in metals. They are shared by all the atoms in the metal and roam all over the place.

shell. The energy level in an atom.

standing waves. The pattern that results at certain frequencies when waves are confined. Also, a name for one of the characters rejected for the film *Dances With Wolves* when they realized waves weren't involved in the film.

Thomson. The scientist who came up with a model of the atom that had positive and negative charges distributed evenly throughout the atom.

valence electron. Any electron in the outer *s* or *p* energy levels.

water. One of the four elements proposed by Empedocles. Something you pay a lot for if it comes in a plastic bottle.

Index

Page numbers in **boldface** type refer to figures.

B

C

D

E

F

G

H

N

O

P

Q

R

S

T

V

W

Z

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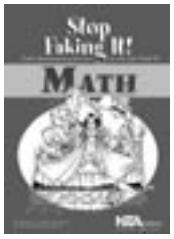

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