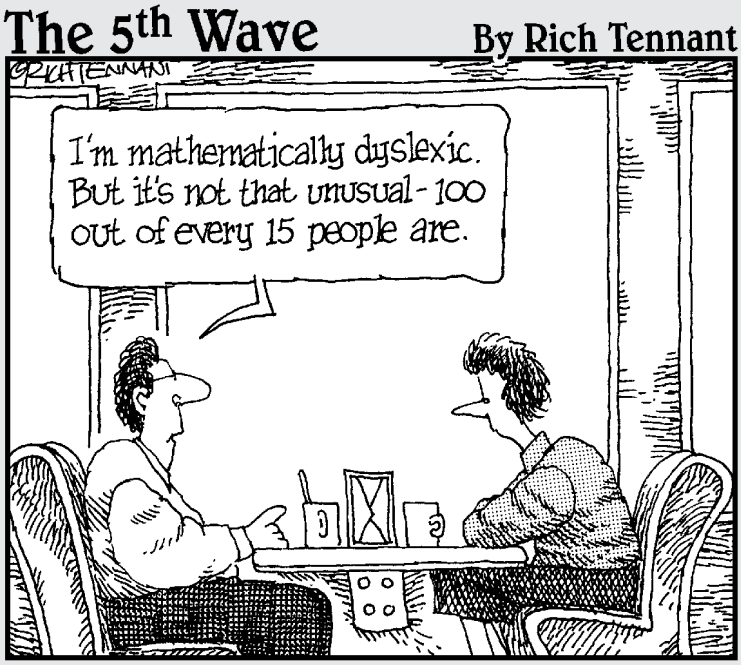
Part I

Basic Concepts of Chemistry



In this part . . .

If you are new to chemistry, it may seem a little frightening. I see students every day who've psyched themselves out by saying so often that they can't do chemistry.

Anyone can figure out chemistry. Anyone can *do* chemistry. If you cook, clean, or simply exist, you're part of the chemical world.

I work with a lot of elementary school children, and they love science. I show them chemical reactions (vinegar plus baking soda, for example), and they go wild. And that's what I hope happens to you.

The chapters of Part I give you a background in chemistry basics. I tell you about matter and the states it can exist in. I talk a little about energy, including the different types and how it's measured. I discuss the microscopic world of the atom and its basic parts. I explain the periodic table, the most useful tool for a chemist. And I cover radioactivity, nuclear reactors, and bombs.

This part takes you on a fun ride, so get your motor running!

Chapter 1

What Is Chemistry, and Why Do I Need to Know Some?

In This Chapter

- Defining the science of chemistry
- Checking out the general areas of chemistry
- Discovering how chemistry is all around you

If you're taking a course in chemistry, you may want to skip this chapter and go right to the area you're having trouble with. But if you bought this book to help you decide whether to take a course in chemistry or to have fun discovering something new, I encourage you to read this chapter. I set the stage for the rest of the book here by showing you what chemistry is, what chemists do, and why you should be interested in chemistry.

I really enjoy chemistry. It's far more than a simple collection of facts and a body of knowledge. I think it's fascinating to watch chemical changes take place, to figure out unknowns, to use instruments, to extend my senses, and to make predictions and figure out why they were right or wrong. It all starts here — with the basics — so welcome to the interesting world of chemistry.

What Exactly Is Chemistry?

Simply put, this whole branch of science is all about *matter,* which is anything that has mass and occupies space. *Chemistry* is the study of the composition and properties of matter and the changes it undergoes.

A lot of chemistry comes into play with that last part — the changes matter undergoes. Matter is made up of either pure substances or mixtures of pure substances. The change from one substance into another is what chemists call a *chemical change,* or *chemical reaction,* and it's a big deal because when it occurs, a brand-new substance is created (see Chapter 2 for the nitty-gritty details).

What is science?

Science is far more than a collection of facts, figures, graphs, and tables. Science is a method for examining the physical universe. It's a way of asking and answering questions. Science is best described by the attitudes of scientists themselves: They're skeptical — they must be able to test phenomena. And they hold onto the results of their experiments tentatively, waiting for another scientist to disprove them. If it can't be tested, it's not science. Scientists wonder, they question, they strive to find out *why*, and they experiment — they have exactly the same attitudes that most small children have before they grow up. Maybe this is a good definition of scientists — they are adults who've never lost that wonder of nature and the desire to know.

Branches in the tree of chemistry

The general field of chemistry is so huge that it was originally subdivided into a number of different areas of specialization. But there's now a tremendous amount of overlap between the different areas of chemistry, just as there is among the various sciences. Here are the traditional fields of chemistry:

- **Analytical chemistry:** This branch is highly involved in the analysis of substances. Chemists from this field of chemistry may be trying to find out what substances are in a mixture *(qualitative analysis)* or how much of a particular substance is present *(quantitative analysis)* in something. A lot of instrumentation is used in analytical chemistry.
- **Biochemistry:** This branch specializes in living organisms and systems. Biochemists study the chemical reactions that occur at the *molecular level* of an organism — the level where items are so small that people can't directly see them. Biochemists study processes such as digestion, metabolism, reproduction, respiration, and so on. Sometimes it's difficult to distinguish between a biochemist and a molecular biologist because they both study living systems at a microscopic level. However, a biochemist really concentrates more on the reactions that are occurring.
- **Biotechnology:** This is a relatively new area of science that is commonly placed with chemistry. It's the application of biochemistry and biology when creating or modifying genetic material or organisms for specific purposes. It's used in such areas as cloning and the creation of disease-resistant crops, and it has the potential for eliminating genetic diseases in the future.
- **Inorganic chemistry:** This branch is involved in the study of inorganic compounds such as salts. It includes the study of the structure and properties of these compounds. It also commonly involves the study of the individual elements of the compounds. Inorganic chemists would probably say that it is the study of everything except carbon, which they leave to the organic chemists.

So what are compounds and elements? Just more of the anatomy of matter. Matter is made up of either pure substances or mixtures of pure substances, and substances themselves are made up of either elements or compounds. (Chapter 2 dissects the anatomy of matter. And, as with all matters of dissection, it's best to be prepared — with a nose plug and an empty stomach.)

- **Organic chemistry:** This is the study of carbon and its compounds. It's probably the most organized of the areas of chemistry — with good reason. There are millions of organic compounds, with thousands more discovered or created each year. Industries such as the polymer industry, the petrochemical industry, and the pharmaceutical industry depend on organic chemists.
- **Physical chemistry:** This branch figures out how and why a chemical system behaves as it does. Physical chemists study the physical properties and behavior of matter and try to develop models and theories that describe this behavior.

The scientific method

Scientific method is normally described as the way scientists go about examining the physical world around them. In fact, there is no one scientific method that everyone uses every time, but the one I cover here describes most of the critical steps scientists go through sooner or later.

Scientists make observations and note facts regarding something in the physical universe. The observations may raise a question or problem that the researcher wants to solve. He or she comes up with a *hypothesis,* a tentative explanation that's consistent with the observations. The researcher then designs an *experiment* to test the hypothesis. This experiment generates observations or facts that can then be used to generate another hypothesis or modify the current one. Then more experiments are designed, and the loop continues.

In good science, this loop never ends. As scientists become more sophisticated in their scientific skills and build better and better instruments, their hypotheses are tested over and over. But a couple of things can come out of this loop. First, a law may be created. A *law* is a generalization of *what* happens in the scientific system being studied. And like the laws that have been created for the judicial system, scientific laws sometimes have to be modified based on new facts. A theory or model may also be proposed. A *theory* or *model* attempts to explain *why* something happens. It's similar to a hypothesis except that it has much more evidence to support it. The power of the theory or model is prediction. If the scientist can use the model to gain a good understanding of the system, then he or she can make predictions based on the model and then check them out with more experimentation. The observations from this experimentation can be used to refine or modify the theory or model, thus establishing another loop in the process. When does it end? Never.

Macroscopic versus microscopic viewpoints

Most chemists that I know operate quite comfortably in two worlds. One is the *macroscopic* world that you and I see, feel, and touch. This is the world of stained lab coats — of weighing out things like sodium chloride to create things like hydrogen gas. This is the world of experiments, or what some nonscientists call the "real world."

But chemists also operate quite comfortably in the *microscopic* world that you and I can't directly see, feel, or touch. Here, chemists work with theories and models. They may measure the volume and pressure of a gas in the macroscopic world, but they have to mentally translate the measurements into how close the gas particles are in the microscopic world.

Scientists often become so accustomed to slipping back and forth between these two worlds that they do so without even realizing it. An occurrence or observation in the macroscopic world generates an idea related to the microscopic world, and vice versa. You may find this flow of ideas disconcerting at first. But as you study chemistry, you'll soon adjust so that it becomes second nature.

Pure versus applied chemistry

In *pure chemistry,* chemists are free to carry out whatever research interests them — or whatever research they can get funded. There is no real expectation of practical application at this point. The researcher simply wants to know for the sake of knowledge. This type of research (often called *basic research*) is most commonly conducted at colleges and universities. The chemist uses undergraduate and graduate students to help conduct the research. The work becomes part of the professional training of the student. The researcher publishes his or her results in professional journals for other chemists to examine and attempt to refute. Funding is almost always a problem, because the experimentation, chemicals, and equipment are quite expensive.

In *applied chemistry,* chemists normally work for private corporations. Their research is directed toward a very specific short-term goal set by the company — product improvement or the development of a disease-resistant strain of corn, for example. Normally, more money is available for equipment and instrumentation with applied chemistry, but there's also the pressure of meeting the company's goals.

These two types of chemistry, pure and applied, share the same basic differences as science and technology. In *science,* the goal is simply the basic acquisition of knowledge. There doesn't need to be any apparent practical application. Science is simply knowledge for knowledge's sake. *Technology* is the application of science toward a very specific goal.

There's a place in our society for science *and* technology — likewise for the two types of chemistry. The pure chemist generates data and information that is then used by the applied chemist. Both types of chemists have their own sets of strengths, problems, and pressures. In fact, because of the dwindling federal research dollars, many universities are becoming much more involved in gaining patents, and they're being paid for technology transfers into the private sector.

So What Does a Chemist Do All Day?

You can group the activities of chemists into these major categories:

- **Chemists analyze substances.** They determine what is in a substance, how much of something is in a substance, or both. They analyze solids, liquids, and gases. They may try to find the active compound in a substance found in nature, or they may analyze water to see how much lead is present.
- **Chemists create, or *synthesize,* new substances.** They may try to make the synthetic version of a substance found in nature, or they may create an entirely new and unique compound. They may try to find a way to synthesize insulin. They may create a new plastic, pill, or paint. Or they may try to find a new, more efficient process to use for the production of an established product.
- **Chemists create models and test the predictive power of theories.** This area of chemistry is referred to as *theoretical chemistry.* Chemists who work in this branch of chemistry use computers to model chemical systems. Theirs is the world of mathematics and computers. Some of these chemists don't even own a lab coat.
- **Chemists measure the physical properties of substances.** They may take new compounds and measure the melting points and boiling points. They may measure the strength of a new polymer strand or determine the octane rating of a new gasoline.

And Where Do Chemists Actually Work?

You may be thinking that all chemists can be found deep in a musty lab, working for some large chemical company, but chemists hold a variety of jobs in a variety of places:

- **Quality control chemist:** These chemists analyze raw materials, intermediate products, and final products for purity to make sure that they fall within specifications. They may also offer technical support for the customer or analyze returned products. Many of these chemists often solve problems when they occur within the manufacturing process.

- **Industrial research chemist:** Chemists in this profession perform a large number of physical and chemical tests on materials. They may develop new products, and they may work on improving existing products. They may work with particular customers to formulate products that meet specific needs. They may also supply technical support to customers.
- **Sales representative:** Chemists may work as sales representatives for companies that sell chemicals or pharmaceuticals. They may call on their customers and let them know of new products being developed. They may also help their customers solve problems.
- **Forensic chemist:** These chemists may analyze samples taken from crime scenes or analyze samples for the presence of drugs. They may also be called to testify in court as expert witnesses.
- **Environmental chemist:** These chemists may work for water purification plants, the Environmental Protection Agency, the Department of Energy, or similar agencies. This type of work appeals to people who like chemistry but also like to get out in nature. They often go out to sites to collect their own samples.
- **Preservationist of art and historical works:** Chemists may work to restore paintings or statues, or they may work to detect forgeries. With air and water pollution destroying works of art daily, these chemists work to preserve our heritage.
- **Chemical educator:** Chemists working as educators may teach physical science and chemistry in public schools. They may also teach at the college or university level. University chemistry teachers often conduct research and work with graduate students. Chemists may even become chemical education specialists for organizations such as the American Chemical Society.

These are just a few of the professions chemists may find themselves in. I didn't even get into law, medicine, technical writing, governmental relations, and consulting. Chemists are involved in almost every aspect of society. Some chemists even write books.

If you aren't interested in becoming a chemist, why should you be interested in chemistry? (The quick answer is probably "to pass a course.") Chemistry is an integral part of our everyday world, and knowing something about chemistry will help you interact more effectively with our chemical environment.