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Organic Chemistry

Chapter 0

Student's Guide to Success in Organic Chemistry

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Chapter Outline

Objectives

- ✓ Understand how organic chemistry impacts the world
- ✓ Learn how to think like an organic chemist so you can succeed in organic chemistry
- ✓ Adapt your own study methods to succeed in this class

"The horror of the moment," the King went on, "I shall never, *never* forget!"
"You will though," the Queen said, "if you don't make a memorandum of it."
—Lewis Carrol

Welcome aboard! You are now at the launching point of a new adventure called Organic Chemistry. To succeed in this adventure, accept the intellectual challenge to look at things from a viewpoint that is perhaps different from any you have ever used before. By committing yourself to hard work and self-discipline, you are ready to make this adventure well worth the journey.

Organic chemistry is the study of the chemistry of the element carbon. What is it about carbon that makes this one element the focus of an entire branch of chemistry? Carbon atoms, unlike most other elements, form stable bonds to each other as well as to a wide variety of other elements. Carbon-containing compounds consist of chains and rings of carbon atoms—bonding in ways that form an endless variety of molecules. At this time, chemists have identified and/or synthesized more than ten million carbon-based compounds, and they add thousands of new organic molecules to this list every month.

0.1 What is Organic Chemistry?

The roots of chemistry go back into antiquity with the development of such techniques as metal smelting, textile dyeing, glass making, and butter and cheese preparation. These early chemical techniques were almost all-empirical discoveries. That is, someone either by accident or observation discovered them. They then passed this knowledge down from one generation to the next. For example, because copper is found in its free metallic state, it was first beaten into various implements. Later it was smelted, being perhaps one of the first metals to be separated from its ore.

Empiricism waned with the Greek philosophers who began the first systematic discussions of the nature of matter and its transformations. There were numerous philosophies and schools that grew up around those philosophers. One that is of particular interest to chemists is that of the atomists. Democritus (460-370 B.C.) elaborated much on the idea of atoms. He thought that atoms were solid particles and that atoms existed in a void but could move about and interact with each other; thus, forming the various natural systems of the world. However, Aristotle and Plato rejected the philosophy of atoms, and it wasn't until the early nineteenth century that Dalton proposed the beginnings of the modern atomic theory.

Socrates, Plato, and Aristotle had the greatest impact on Greek philosophy. Socrates felt that studying the nature of man and his relationships was much more important than studying the science of nature. He did benefit the later development of science by insisting that definitions and classifications be clear, that arguments be logical and ordered, and that there be a rational skepticism. Plato adopted the philosophy that there were four elements: fire, air, water, and earth. Aristotle added to those four elements four associated qualities: hot, cold, wet, and dry. He believed that each element possessed two of these qualities, as illustrated in Figure 0.1.

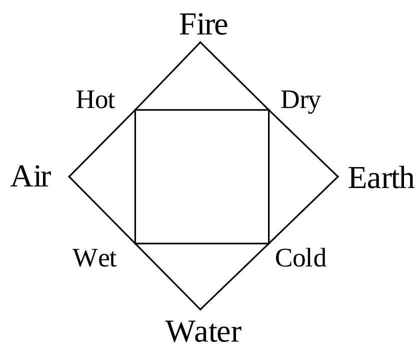


Figure 0.1. The relationship between the four elements and their associated qualities. This diagram frequently appears in alchemy literature.

According to this philosophy, one element might be changed (transmuted) into another element by changing its qualities. For example, earth was dry and cold, but it could be transmuted into fire by changing its qualities to hot and dry.

These theories remained important for nearly two thousand years. Of greatest significance was the scientific work that took place in Alexandria. Unfortunately, little of it was in the field of chemistry.

It was in Alexandria, toward the end of the first century BC, that western **alchemy** began growing. Alchemy was a mixture of philosophy, religious, or spiritual, ideas, astrology, and empirical technical skills. Based on the theory that all matter consisted of fire, air, water, and earth with the associated qualities of hot, cold, wet and dry and that by changing the qualities of one form of matter you could change it to another form, the philosophers thought if they systematically changed matter from one form to another in time they could obtain the perfect metal. Not only were they working to form the perfect metal but also to form an elixir of life that would give them spiritual perfection.

Alchemy is the philosophical and primitively empirical study of physical and chemical transformations.

From Alexandria, alchemy quickly spread throughout the Western world. For the next fifteen hundred years, its many practitioners persuaded wealthy patrons to support them in their research with the promise that unlimited wealth was just around the corner—just as soon as they could convert lead or iron into gold or silver.

Don't think that because alchemists promised to convert base materials into precious metals that they were just con-artists promising something for nothing. Many alchemists truly believed that somewhere in nature there existed a procedure that would form precious metals from base materials. As they worked to find this procedure, they learned much about science, although they were not scientists in a modern sense. What alchemy provided to science was the experimental base from which modern chemical theories arose.

Because alchemists promised impossible chemical feats and did not follow modern scientific methods, historians often call this time period the “dark age” of science. However, their logic was quite sound. Their goal to change matter from one form to another was the result of looking at the many dramatic changes they could see in nature. For example, in a fire, wood simply “disappeared” leaving a small amount of ashes. Thus, as the alchemists observed dramatic changes such as this, they reasoned that it should be as easy to make other sorts of changes—such as changing lead into gold. They had no way of knowing that converting lead to gold involved a totally different type of change than that of using fire to turn wood into ashes.

The move toward modern chemistry took a long time. Physics and medicine had provided an experimental base, but first the philosopher’s attitude toward nature had to change to a more inductive approach. That is, as René Descartes advocated, accept only those things that you can prove. Perhaps the biggest obstacle to modern chemistry was that of chemical identity. There was the need to replace the alchemist’s four elements with the understanding of atoms. Scientists needed to understand that the identity of a substance stayed the same even when that substance became a part of another substance. For example, copper is always copper even when mixed with zinc to form bronze, an alloy of copper. Robert Boyle (1627-1691) did much to do away with the view of the four elements, as well as to begin the study of gases (or air). Many scientists studied gases and isolated a number of pure gaseous compounds, but they all thought that these gases were either very pure air or very impure air. Antoine Lavoisier (1743-1794) finally moved chemistry into its own as a modern science with his recognition that oxygen was not just very pure air, it was a completely separate element.

Early in the nineteenth century, as modern chemistry began developing, chemists mostly ignored organic chemistry, viewing it as either medically or biologically related because nearly all the known organic compounds were derived from living organisms, both plant and animal. An exception to this was Lavoisier, who was very interested in organic chemistry and considered it to be a part of chemistry. He looked at some organic compounds and found that they all contained carbon.

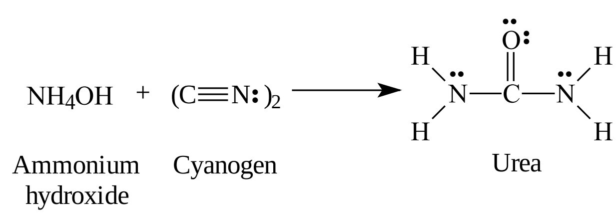
Because organic compounds were much more complex and unstable than the inorganic compounds being synthesized at the time, chemists had not knowingly prepared any and, in fact, thought that they were impossible to prepare. They believed that these compounds came only from living organisms. That is, the formation of the known organic compounds, such as urea, starches, oils, and sugar, required some "vital force" possessed by living organisms. Thus, organic chemistry became the study of compounds having a vital force, or **vitalism**. Some chemists felt that, because of the "vital force," organic compounds did not follow the same rules that other compounds did.

Vitalism is the belief that the synthesis of organic compounds requires the "vital force" from some living organism.

Unaffected by the attitudes concerning organic chemistry, Michel Chevreul set out to study the composition of fats using the process of saponification, or soap making. In 1816, Chevreul separated soap into several pure organic compounds and found that these compounds were very different from the fat that he had started with. He had unwittingly dealt vitalism a major blow.

To do his work, Chevreul first made soap. He repeated the process many times making the soap from several sources of fat and alkali. Then, after he separated the soap from the glycerin, he separated the soap into its various fatty acids. He called these compounds fatty acids because he had isolated them from the soap, which he had prepared from animal fat. Previously people had not understood that a chemical reaction took place during the soap making process. They thought that soap was simply a combination of the fat and alkali. Unfortunately, other chemists took a long time to recognize the significance of Chevreul's work.

Another chemist that brought vitalism to its end was Friedrich Wöhler with his synthesis of urea in 1828—as he said, "without the use of a kidney". The following reaction is the synthesis of urea using the starting material aqueous ammonium hydroxide and cyanogen.

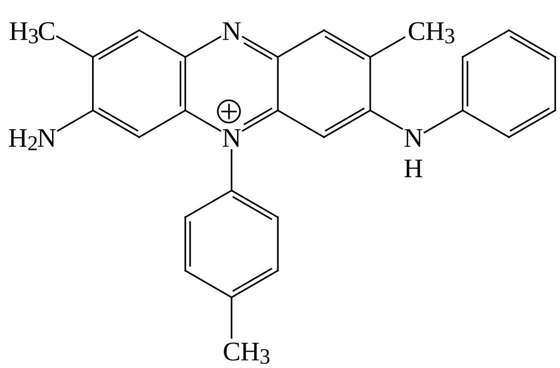


Wöhler's goal was not to synthesize urea; he was trying to make ammonium cyanate (NH_4OCN), a compound he needed for his research. In fact, he may have become frustrated because he tried to make ammonium cyanate by several different routes. He tried reacting silver cyanate with ammonium chloride, reasoning that silver chloride is insoluble and would precipitate from solution. He tried reacting lead cyanate with ammonium hydroxide. Finally, he tried aqueous ammonium hydroxide and cyanogen. But, every attempt led to the same white crystalline substance that was *not* the desired product.

Wöhler made his mark in the annals of chemistry by deciding to identify this unknown substance. Once he identified it as urea, he also recognized the importance of his discovery. As he wrote in 1828 "[The] research gave the unexpected result . . . that is the more noteworthy inasmuch as it furnishes an example of the artificial production of an organic, indeed a so-called animal substance from inorganic materials."

Chevreul and Wöhler had forever altered the study of organic chemistry. As other chemists looked at the work that Chevreul and Wöhler had done, they saw that chemists could indeed synthesize compounds of carbon without a living organism. They then began making carbon compounds and studying them. Soon many chemists were achieving remarkable successes in the new art of the synthesis of organic compounds. Thus began the study of organic compounds.

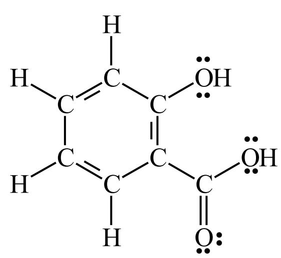
Inevitably, someone would take these new developments from the organic chemistry research laboratory and find ways to market them. William Henry Perkin was the first to do so. In 1856, at the age of 18, while on vacation from London's Royal College of Chemistry, Perkin was working in his home laboratory. While naively attempting to make quinine, a task not accomplished until 1944, he accidentally synthesized the dye now called Perkin's mauve. The next year, using money borrowed from his father, he built a factory and marketed the new dye. From there, he worked with coal tar and found that coal tar was a rich source of starting materials for a variety of new dyes.



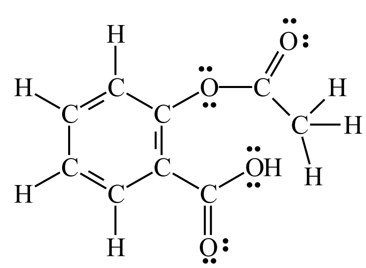
Perkin's mauve

Another step in the progress of organic chemistry was the drilling of the first oil wells in Pennsylvania in 1859. The oil pumped from those wells provided a new, cheap, and abundant source of carbon compounds. Today the petrochemical industry supplies the raw materials for thousands of different products including a variety of things from explosives and fuels to pharmaceuticals and agricultural chemicals.

In 1895, the Bayer Company of Germany established the pharmaceutical industry. Then in 1899, the company began marketing aspirin, as a result of the work of Felix Hoffmann. Hoffmann learned how to prepare aspirin from natural salicylic acid. For hundreds of years, people had chewed the bark of the willow tree to relieve minor pain. Willow tree bark contains the analgesic salicylic acid. Aspirin is superior to salicylic acid as an analgesic because it produces less irritation to the stomach and effectively treats the pain.



Salicylic acid



Aspirin

In the early days of chemistry, chemists learned a great deal about the simple compounds not usually found in living systems, but they learned very little about the organic compounds that are found in living systems. They were far too complex for the simple analytical tools available in the nineteenth century and the early twentieth century. Thus, progress was slow in understanding the chemistry of living systems. The subsequent development of powerful analytical tools allowed many insights into biologically important molecules and opened up new areas for scientific study.

0.2 Organic Chemistry in the Everyday World

Organic chemistry touches every aspect of your life. This includes such areas as the clothes you wear, the food you eat, and the car you drive. Common to each of these items are chemical compounds based on the element carbon. Organic chemistry has both positive and negative attributes, and organic chemistry involves you.

All living creatures, both plant and animal, consist largely of complex carbon-containing molecules. These molecules provide for the day-to-day operation and maintenance of each organism as well as for the continuance of the species. Interestingly, as chemists learned how to synthesize these complex molecules of life and the molecules that interact with them, organic chemistry came back to its roots. A part of the beginnings of organic chemistry was the study of compounds derived from the "organs" of living creatures—thus the name organic chemistry. Now the knowledge gained from that research provides the basis for healing the diseases of many of those organs.

Looking in a totally different direction for the presence of carbon atoms in your life, what can you find that is more commonplace than plastic? You use plastics, or polymers, virtually all day long from the "disposable" packaging of your bath toiletries to the sophisticated polymeric materials in your car and computer. The plastics that make up all these items are based on organic compounds. The polymer industry has impacted modern society more than any other industry.

The above discussion covers some of the positive contributions of organic chemistry. Unfortunately, however, organic chemistry has made some negative contributions to the world too. There is a wide variety of commercial products that do not readily degrade when discarded or that cause other sorts of environmental problems. In spite of their usefulness, plastics are among those products. Because of the negative side of plastic, and other products, chemistry has gained a bad reputation in modern society. Adding to this reputation are the unscrupulous entrepreneurs who inappropriately dump hazardous materials thus contaminating the soil, air, and water.

Few chemists and chemical companies intentionally market products that will cause harm to a customer or to the environment. Those that do usually are considering only how much profit they can make and may even cover up evidence showing harm from their product. In many cases, the problems with a product come to light after the product reaches the market—sometimes long after reaching the market. This may occur because the company simply did not thoroughly test its product. Also, the shortfall in testing is often in the areas where the customer uses the product in ways unrelated to its intended use. Most chemists and chemical industries are good citizens with sound environmental concerns.

So, besides being a consumer, how could you fit into organic chemistry? Are you good at thinking up new ideas or looking at old ideas in new ways? The marketplace always welcomes new products. Do you have a concern for the environment? There is a worldwide need for solutions to the multitude of environmental problems and to find new products to replace those products causing harm to the environment. Related to the environment are the needs for solutions to the many other problems of modern society. Have you always been one to ask, "Why?" and "How does it work?" Chemists have just begun to learn about chemistry. Perhaps you could do research in chemistry—just because it's there. Or you could use organic chemistry as an important foundation of your profession in medicine—either as a medical researcher or as a physician working with patients. Both biochemistry and many areas of biology depend heavily on a thorough understanding of organic chemistry. Biochemistry is the study of the molecules found in living organisms. Biology is increasingly directed to molecular biology, which is designed to learn more about living organisms by understanding the molecular processes of life.

0.3 Organic Chemists Are People, Too

At the root of all science, including organic chemistry, is people's unquenchable curiosity about the world and themselves. Everywhere are objects, living organisms, and events that people have had questions about. Scientists investigated these questions and discovered other questions. They investigated these new questions and found still more questions. Research, they learned, not only answers questions but uncovers new ones. Although scientists have learned many answers, they also have found that the answers to some questions must wait for the development of better investigative methods and tools. The job of scientists is to find answers to the multitude of questions about the world and to develop better methods and tools to answer the more and more sophisticated questions that they come up with along the way.

Because much of the world is based on the chemistry of carbon, organic chemists have provided many answers to the questions about the world. Many creative and curious people have been attracted to organic chemistry. The following stories illustrate the hard work and ingenuity of two such chemists.

In 1874, Othmer Zeidler reported the synthesis of DDT in his doctoral dissertation. Some years later, Paul Hermann Müller discovered the insecticidal properties of DDT and in 1948 received the Nobel Prize in Medicine and Physiology for his discovery. Today DDT has a bad reputation because of its persistence in the environment. Its intended use was to kill disease-bearing insects, but it also caused harm to a number of birds and animals. DDT is no longer used in most areas of the world, but in the 1940s it was a “magic bullet” that killed many disease-bearing insects and saved many hundreds of thousands of lives. During World War II, the military used DDT, but it was not available for civilian use until Frank Mayo happened to read about it.

Frank Mayo is an example of an ambitious person who, with determination and hard work, coupled with a sound chemical foundation, made an impact on society (See Friedman, *J. Chem. Educ.*, **1992**, 69, 362). Mayo attended Georgia Tech leaving just one semester from completing the three year degree in chemistry. He turned down a job offer for eighteen dollars per week because he thought he could earn more working on his father's farm.

A few years later he began manufacturing and marketing chlorine based bleaching compounds. In 1944, while looking for other products to manufacture, Mayo happened on an article in the *Atlanta Constitution* describing DDT and its uses. He became interested. DDT was available only to the military; but even there, it was available only in limited quantities. The article stated that the synthesis for DDT was classified. However, it did give one important clue—a brief mention of the original synthesis by Zeidler in Germany. That was just enough information for a determined chemist!

Mayo knew that usually graduate students published their doctoral dissertations four to six months after graduation. He also knew that Othmer Zeidler received his degree in May or June of 1874, so Mayo expected to find the published report in the renowned journal *Berichte der Deutschen Chemischen Gesellschaft* (Reports of the German Chemical Society) by October, 1874.

Mayo went to the Georgia Tech library but found they did not begin subscribing to *Berichte* until 1910. Nearby Emory University began in 1915. He next decided to try the University of Georgia library 75 miles away in Athens. Since his daughter Bebe was a student there, he phoned her and asked her to check the library for him.

She found that indeed the University of Georgia had the 1874 issues of *Berichte*, but they were in boxes stored in the attic of the library. Only after many delays and much persuasion did Bebe gain permission to look through the issues *Berichte* in the attic. The librarians were notably reluctant to get them out of storage for a freshman who was studying neither German nor Chemistry. Bebe examined the title pages of the 1874 volume of *Berichte* beginning with October. "Believe it or not," says Mayo, "There it was, in the October issue." Word for word in the unfamiliar German, Bebe copied the paper by hand, then she called her father.

Mayo rushed to Athens, only to arrive after visiting hours in the dormitory. They wouldn't even let a father see his daughter after visiting hours! He drove around the dormitory, parked under his daughter's window and honked the horn. Bebe placed the transcript in an envelope and threw it out the window. Carefully shielding the paper from the falling rain, he read Bebe's copy in the headlight of the car then immediately drove back to Atlanta. He had the synthesis of DDT!

The synthesis required three ingredients: chlorobenzene, sulfuric acid, and chloral. He already had the chlorobenzene and sulfuric acid, but he had no chloral. Ignoring the fact that it was midnight, he drove to the neighborhood druggist and asked for a pound of chloral. The sleepy druggist grumpily informed him that he needed a prescription, and that no physician was likely to give him a prescription for a pound of the stuff. The typical prescription for chloral was measured in minims (about 16 minims per milliliter).

Mayo explained the reason for wanting the chloral, and the druggist finally agreed to sell him a pound.

With the precious chloral in hand, Mayo went home to try to make DDT. He measured the chemicals into a fruit jar packed in ice, using a wooden kitchen spoon to stir the mixture. Twenty minutes later, floating white lumps covered the top of the liquid. He separated the solid from the mixture with a buttermilk strainer and dried the powder. Then he slept.

The next morning, he made up a 5% solution in mineral spirits and sprayed the laundry area of his basement. Fleas from his dogs infested the area. An hour later, he and his wife returned to the basement. "Not a flea jumped to my wife's ankles," he said. "Nothing happened—no fleas! The fleas, formerly plentiful, were dead. Cockroaches were lying with their feet in the air as if waving good bye to me. I was a happy man."

Mayo then built a plant to manufacture DDT. Because of the war, he could not buy the equipment he needed. However, being resourceful, he built his plant with scraps and old metal drums that most people would consider junk. Mayo made hundreds of thousands of pounds of DDT powder and DDT solutions in deodorized kerosene and shipped it all over the world. Because of the benefit DDT gave to people, Mayo received much praise. Later, problems showed up that scientists traced to DDT so he stopped making and selling it. Since the banning of DDT, insect born diseases are again on the rise, but because DDT causes damage to helpful animals, it is not an acceptable insecticide. So far no one has discovered a good substitute.

Are you ever heading in one direction with a particular project only to find it turning out differently than you had expected? Do you just junk the project, or do you find yourself trying to figure out what went wrong or how you can use the project some other way? Many of the great discoveries of chemistry were made because the chemist investigated the reasons for an unexpected result. That was the case for Roy J. Plunkett, a young Ph.D. chemist who graduated from Ohio State University in 1936.

Plunkett was working for DuPont attempting to find a non-toxic refrigerant. On April 6, 1938, he and his assistant, Jack Rebok, opened the valve on a cylinder of tetrafluoroethylene to begin an experiment. No tetrafluoroethylene came out. In fact, nothing came out, although the weight of the tank indicated it should be full. He pushed a wire into the valve to determine if it was blocked. The wire went in freely. Plunkett had no understanding of what was wrong, but instead of discarding the "empty" tank and getting another to continue his research, he decided to investigate. Sawing the tank open, he found it filled with a waxy white powder. The molecules of tetrafluoroethylene had reacted together to form a polymer, or plastic, that they called polytetrafluoroethylene.

No one had ever observed the polymerization of tetrafluoroethylene before, but somehow it had occurred inside an otherwise “empty” tank. What caused it? On further investigation, Plunkett found some iron oxide inside the tank and discovered that it had catalyzed the polymerization reaction. Plunkett and other DuPont investigators soon developed ways to make polytetrafluoroethylene.

This new polymer had some remarkable properties. It was inert—it would not react with either strong acids or strong bases. It was heat stable, and no solvent could dissolve it. It was also extremely slippery. In spite of these interesting properties, if it had not been for World War II, probably no one would have done anything with it. Tetrafluoroethylene was too expensive.

General Leslie R. Groves happened to hear about the new material and asked to test it. General Groves was in charge of the Manhattan Project, the group working to develop the atomic bomb. In their research, they used enriched uranium. To make the enriched uranium, they converted uranium to uranium hexafluoride, an extremely corrosive gas. The project needed a gasket material that was resistant to uranium hexafluoride, so DuPont made some gaskets and valves for Groves. The scientists at the Manhattan Project tested them and found them very resistant to uranium hexafluoride. DuPont manufactured Plunkett's polymer for the Manhattan Project under the name Teflon™.

Unlike DDT, Teflon's usefulness has stretched well beyond its wartime beginnings. Who hasn't used Teflon coated cookware? Of greater significance than the cookware is the fact that Teflon is a substance that the body does not reject. Thus, millions of people have benefited by receiving such things as artificial hips and knee joints or aortas and pacemakers made of Teflon. Another use of Teflon is in the space program. Space suits, wire and cable insulation, spaceship nose cones, and fuel tanks all use Teflon.

0.4 Learning to Think Like a Chemist

To learn to think like an organic chemist, you must first know how an organic chemist thinks. The following three points are an overview of their thought processes. Also, these three points are goals for you as you study this book. (1) Organic chemists learn the facts. (2) They use these facts to construct concepts by organizing the facts into a coherent picture. (3) As organic chemists learn new facts, they update their picture of concepts.

From the scientific viewpoint, facts are important because facts are the basis of science. A fact is an observation based on experimentation. Scientists, and that includes organic chemists, form their hypotheses based on the facts that they know about a certain topic. They make a speculation based on the hypothesis and do some experiments based on that speculation. These experiments lead to new facts, which lead to an updated hypothesis and further speculation and more experiments. Thus, the whole process in all sciences is designed to produce a coherent but expanding understanding of the universe.

Facts alone are not important to organic chemists. What is important is the way those facts fit together to form a coherent picture. Most organic chemists can produce an amazing variety of facts within the context of a particular concept. However, if asked to provide a list of the facts of organic chemistry, an organic chemist would probably be unable to produce a very impressive list. On the other hand, many beginning organic chemistry students can produce an amazing variety of facts on demand, but have little idea how they fit into a clear picture. A part of thinking like an organic chemist is to learn as many facts as you can about organic chemistry and, at the same time, to continually organize those facts in a way that allows you to synthesize new ideas. This method of learning can help you better understand and use the facts.

The important part of learning organic chemistry is the concepts you construct from the set of facts that you learn. Chemistry is, above all, a science. As a science, the only way to learn anything meaningful about organic chemistry is to work with the concepts. These concepts are not inviolable. They are subject to constant reconstruction and reinterpretation as you learn new facts. The authors of this book and your lecturer can only present the facts and provide you with the vehicle from which you can build your own understanding.

0.5 Developing Study Methods for Success

The key to your success in organic chemistry is in what you learn. Build your foundation to gain this knowledge by carefully studying the book and actively participating in the lectures. The more you apply your developing knowledge to understanding the design of the various organic syntheses and reaction mechanisms, the more you will grow in creativity as a student of organic chemistry.

Studying organic chemistry is like combining the elements of a foreign language class with the elements of a logic, or math, class. As with a foreign language, you must learn the vocabulary (names of compounds, chemical structures, reagents, and reactions), as well as the grammar (electron movements). As with a math class, you must understand the logic (reaction mechanisms). You combine these elements by practicing the grammar and vocabulary; then following the logic as you apply your knowledge to new situations (working the exercises in your book). Finally, you demonstrate your mastery of both the grammar and the logic (by doing well on the examinations your instructor writes).

To succeed in this class, you must develop a consistent knowledge base of concepts, theories, and techniques. In other words, what you learn in the early chapters is essential for your understanding of the material in later chapters. Failure to retain the things that you have studied will make learning organic chemistry seem overwhelming. When you study, make it your central objective to thoroughly understand the concepts, theories, and techniques being covered, then retain them. Could you repeat that, please? ***When you study, make it your central objective to thoroughly understand the concepts, theories, and techniques being covered, then retain them.*** These concepts, theories, and techniques are your knowledge base and the foundation for all of your continued efforts in learning organic chemistry.

Developing and maintaining your knowledge base of organic chemistry requires some learning strategies that are different from those used for many other classes. Primarily, learning organic chemistry requires consistent time, effort, and, most of all, thought. Organic chemistry has a reputation for being a difficult subject to master because it covers a lot of information and some students struggle over some of the concepts. Regular study diminishes this difficulty level. Some people can stuff in lists of facts in an all night cram, but few people can learn facts and the accompanying logic, then integrate those facts and the logic with previously learned facts and logic in a last minute effort. The most important move you can make on the road to success in organic chemistry is to establish a regular program of study.

Ideally, a schedule of regular study involves five steps.

Step 1 When your instructor assigns a new chapter, quickly read through it before your instructor lectures on it. Your goal is not to get everything from the chapter in this first reading but to get an overview of the main ideas.

Step 2 Immediately after the lecture, reread the material and work the in-text exercises. If you have difficulty with an exercise, then review your lecture notes and reread the material in that section. Be sure that you understand that section and can work the exercises before continuing.

Step 3 As you read and work the in-text exercises, begin memorizing the important facts from the chapter. Remember that memorizing facts is an essential part, but ***only*** a part, of success in organic chemistry.

Step 4 After you finish reading the chapter and working the in-text exercises; develop your logic skill by working the end of the chapter exercises.

Step 5 Prepare for the examination by working more of the end of chapter exercises. Your problem solving skills will show if you grasp what you have studied. Ask questions. Find someone who needs help and teach them what you have learned.

Problem solving in the real world of scientists seldom proceeds in the organized fashion that most textbook authors, classroom instructors, and scientists would have you think. Problem solving requires a lot of struggling, puzzling, trial-and-error, false starts, and dead ends. Chemists do not wait for divine inspiration to solve a problem. Instead, they write down what they know, then analyze and manipulate that information. When the next step becomes apparent, they take that step, then stop again to analyze and manipulate the new information. In this way chemists work toward a solution to the problem. As with them, so with you—the more problems you solve, the easier it will become to solve them.

There are two general strategies for problem solving. The most common form of problem solving is rote problem solving. With rote problem solving, you need to know only the proper formula to reach the correct answer. As long as you remember the formula and make no mistakes plugging in the facts and solving the formula, you will solve the problem correctly. This form of problem solving requires little understanding of the formula. Less common, but far more useful, is conceptual problem solving. Here you need to analyze and rearrange the statement of the problem to identify the underlying concepts involved. Once you identify the underlying concepts, you apply those concepts to the data and solve the problem.

Successful chemists use conceptual problem solving. To succeed as an organic chemistry student, you must also learn how to solve problems conceptually. Skill with conceptual problem solving requires much practice. When working the exercises in this book or those on your quizzes and examinations, seldom can you rely on "divine inspiration" for the solution. You must systematically dissect the exercise and apply the underlying principles of the particular concepts involved to find the solution. Even with this systematic work, many students find that, at first, they come up with the wrong answer to a problem. Don't let wrong answers discourage you; right answers will come more and more readily as you gain a larger foundation of principles and logic to work with.

The exercises in this book fit into three groups. The first group includes the exercises within the chapter. Work them as practice in learning the principles you have just read and to examine your grasp of those principles. The second group of exercises is the first few exercises at the end of the chapter. They are similar to those contained in the chapter. The final group of exercises are the remaining exercises at the end of the chapter. Many require that you synthesize a new idea from concepts in the current chapter or to integrate concepts from the current chapter with concepts from previous chapters. Work them to assist you in the integration of the material in the new chapter with the material you have previously learned.

The aim of this book is to provide you with the fundamentals of organic chemistry in a systematic, reasoned, and clear fashion. The field of organic chemistry is so broad that even a book of this size can give you only an overview of the subject. Within this overview look for the relationships of the various chemical reactions as they fit under the common reaction mechanisms. Have fun!

Key Ideas from Chapter 0

❏ Organic chemistry as a science is less than two hundred years old. However, in that brief time, it has made a major impact on the quality of life for most of the population of the world.

❏ Organic chemists develop an important strategy for learning organic chemistry. When a new fact is learned, it is integrated with the facts the chemist already knows. This new fact often alters the organic chemist’s view of the discipline or provides some new insight into organic chemistry.

❏ Learning organic chemistry requires that you spend regular time learning the facts and working to develop a learning strategy similar to that of an organic chemist.