

### Earnings

Median annual earnings of atmospheric scientists in 2000 were \$58,510. The middle 50 percent earned between \$39,780 and \$72,740. The lowest 10 percent earned less than \$29,880, and the highest 10 percent earned more than \$89,060.

The average salary for meteorologists in nonsupervisory, supervisory, and managerial positions employed by the Federal Government was about \$68,100 in 2001. Meteorologists in the Federal Government with a bachelor's degree and no experience received a starting salary of \$24,245 or \$29,440, depending on their college grades. Those with a master's degree could start at \$29,440 or \$36,606; those with the Ph.D., at \$47,039 or \$59,661. Beginning salaries for all degree levels are slightly higher in selected areas of the country where the prevailing local pay level is higher.

### Related Occupations

Workers in other occupations concerned with the physical environment include environmental scientists and geoscientists, physicists and astronomers, mathematicians, and civil, chemical, and environmental engineers.

### Sources of Additional Information

Information about careers in meteorology is available from:

► American Meteorological Society, 45 Beacon St., Boston, MA 02108. Internet: <http://www.ametsoc.org/AMS>

Information on obtaining a meteorologist position with the Federal Government is available from the Office of Personnel Management through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the Internet site: <http://www.usajobs.opm.gov>.

## Chemists and Materials Scientists

(O\*NET 19-2031.00, 19-2032.00)

### Significant Points

- A bachelor's degree in chemistry or a related discipline is the minimum educational requirement; however, many research jobs require a Ph.D.
- Job growth will be concentrated in pharmaceutical companies and in research and testing services firms.
- Strong demand will exist for those with a master's or Ph.D. degree.

### Nature of the Work

Everything in the environment, whether naturally occurring or of human design, is composed of chemicals. Chemists and materials scientists search for and use new knowledge about chemicals. Chemical research has led to the discovery and development of new and improved synthetic fibers, paints, adhesives, drugs, cosmetics, electronic components, lubricants, and thousands of other products. Chemists and materials scientists also develop processes that save energy and reduce pollution, such as improved oil refining and petrochemical processing methods. Research on the chemistry of living things spurs advances in medicine, agriculture, food processing, and other fields.

Materials scientists research and study the structures and chemical properties of various materials to develop new products or enhance existing ones. They also determine ways to strengthen or

combine materials or develop new materials for use in a variety of products. Materials science encompasses the natural and synthetic materials used in a wide range of products and structures, from airplanes, cars, and bridges to clothing and household goods. Companies whose products are made of metals, ceramics, and rubber employ most material scientists. Other applications of this field include studies of superconducting materials, graphite materials, integrated-circuit chips, and fuel cells. Materials scientists, applying chemistry and physics, study all aspects of these materials. Chemistry plays an increasingly dominant role in materials science, because it provides information about the structure and composition of materials.

Many chemists and materials scientists work in research and development (R&D). In basic research, they investigate properties, composition, and structure of matter and the laws that govern the combination of elements and reactions of substances. In applied R&D, they create new products and processes or improve existing ones, often using knowledge gained from basic research. For example, synthetic rubber and plastics resulted from research on small molecules uniting to form large ones, a process called polymerization. R&D chemists and material scientists use computers and a wide variety of sophisticated laboratory instrumentation for modeling and simulation in their work.

The use of computers to analyze complex data has had the dramatic impact of allowing chemists and materials scientists to practice combinatorial chemistry. This technique makes and tests large quantities of chemical compounds simultaneously in order to find compounds with desired properties. As an integral part of drug and materials discovery, combinatorial chemistry speeds up material designing and research and development, permitting useful compounds to be developed more quickly and inexpensively than was formerly possible. Combinatorial chemistry has allowed chemists to produce thousands of compounds each year and to assist in the completion of sequencing human genes.

*Chemists* also work in production and quality control in chemical manufacturing plants. They prepare instructions for plant workers that specify ingredients, mixing times, and temperatures for each stage in the process. They also monitor automated processes to ensure proper product yield, and test samples of raw materials or finished products to ensure that they meet industry and government standards, including the regulations governing pollution. Chemists report and document test results and analyze those results in hopes of further improving existing theories or developing new test methods.

Chemists often specialize in a subfield. *Analytical chemists* determine the structure, composition, and nature of substances by examining and identifying the various elements or compounds that make up a substance. They are absolutely crucial to the pharmaceutical industry because pharmaceutical companies need to know the identity of compounds that they hope to turn into drugs. Furthermore, they study the relations and interactions of the parts of compounds and develop analytical techniques. They also identify the presence and concentration of chemical pollutants in air, water, and soil. *Organic chemists* study the chemistry of the vast number of carbon compounds that make up all living things. Organic chemists who synthesize elements or simple compounds to create new compounds or substances that have different properties and applications have developed many commercial products, such as drugs, plastics, and elastomers (elastic substances similar to rubber). *Inorganic chemists* study compounds consisting mainly of elements other than carbon, such as those in electronic components. *Physical and theoretical chemists* study the physical characteristics of atoms and molecules and the theoretical properties of matter, and investigate how chemical reactions work. Their research may result in new and better energy sources. *Macromolecular chemists* study the behavior of atoms and



*Job growth for chemists will be concentrated in research and testing service firms.*

molecules. *Medicinal chemists* study the structural properties of compounds intended for applications to human medicine. *Materials chemists* study and develop new materials to improve existing products or make new ones. In fact, virtually all chemists are involved in this quest in one way or another. Developments in the field of chemistry that involve life sciences will expand, resulting in more interaction between biologists and chemists. (*Biochemists*, whose work encompasses both biology and chemistry, are discussed in the *Handbook* statement on biological scientists).

Materials scientists also may specialize in specific areas such as ceramics or metals.

### Working Conditions

Chemists and materials scientists usually work regular hours in offices and laboratories. Research and development chemists and materials scientists spend much time in laboratories, but also work in offices when they do theoretical research or plan, record, and report on their lab research. Although some laboratories are small, others are large enough to incorporate prototype chemical manufacturing facilities as well as advanced equipment for chemists. In addition to working in a laboratory, materials scientists also work with engineers and processing specialists in industrial manufacturing facilities. After a material is sold, materials scientists often help customers tailor the material to suit their needs. Chemists do some of their work in a chemical plant or outdoors—while gathering water samples to test for pollutants, for example. Some chemists are

exposed to health or safety hazards when handling certain chemicals, but there is little risk if proper procedures are followed.

### Employment

Chemists and materials scientists held about 92,000 jobs in 2000. Over half of all chemists are employed in manufacturing firms—mostly in the chemical manufacturing industry, which includes firms that produce plastics and synthetic materials, drugs, soaps and cleaners, paints, industrial organic chemicals, and other miscellaneous chemical products. Chemists also work for State and local governments and for Federal agencies. The U.S. Department of Health and Human Services (which includes the Food and Drug Administration, the National Institutes of Health, and the Center for Disease Control) is the major Federal employer of chemists. The Departments of Defense and Agriculture and the Environmental Protection Agency also employ chemists. Other chemists work for research, development, and testing services. In addition, thousands of persons with a background in chemistry and materials science hold teaching positions in high schools and in colleges and universities. (See the two statements on teachers—postsecondary and teachers—preschool, kindergarten, elementary, middle, and secondary elsewhere in the *Handbook*.)

Chemists and materials scientists are employed in all parts of the country, but they are mainly concentrated in large industrial areas.

### Training, Other Qualifications, and Advancement

A bachelor's degree in chemistry or a related discipline is usually the minimum educational requirement for entry-level chemist jobs. However, many research jobs require a Ph.D. While some materials scientists hold a degree in materials science, a bachelor's degree in chemistry, physics, or electric engineering also is accepted. For research and development jobs, a Ph.D. in materials science or a related science is often required.

Many colleges and universities offer a bachelor's degree program in chemistry; about 620 are approved by the American Chemical Society (ACS). The number of colleges that offer a degree program in materials science is small, but gradually increasing. Several hundred colleges and universities also offer advanced degree programs in chemistry; around 320 master's programs, and about 190 doctoral programs are ACS-approved.

Students planning careers as chemists and materials scientists should take courses in science and mathematics, and should like working with their hands building scientific apparatus and performing laboratory experiments and computer modeling. Perseverance, curiosity, and the ability to concentrate on detail and to work independently are essential. Interaction among specialists in this field is increasing, especially for chemists in drug development. One type of chemist often relies on the findings of another type of chemist. For example, an organic chemist must understand findings on the identity of compounds prepared by an analytical chemist.

In addition to required courses in analytical, inorganic, organic, and physical chemistry, undergraduate chemistry majors usually study biological sciences, mathematics, and physics. Those interested in the environmental field should also take courses in environmental studies and become familiar with current legislation and regulations. Computer courses are essential, as employers increasingly prefer job applicants who are able to apply computer skills to modeling and simulation tasks and operate computerized laboratory equipment. This is increasingly important as combinatorial chemistry techniques are more widely applied. Scientists with outdated skills or who are unfamiliar with combinatorial chemistry are often retrained by companies in-house.

Because research and development chemists and materials scientists are increasingly expected to work on interdisciplinary teams,

some understanding of other disciplines, including business and marketing or economics, is desirable, along with leadership ability and good oral and written communication skills. Experience, either in academic laboratories or through internships, fellowships, or co-op programs in industry, also is useful. Some employers of research chemists, particularly in the pharmaceutical industry, prefer to hire individuals with several years of postdoctoral experience.

Graduate students typically specialize in a subfield of chemistry, such as analytical chemistry or polymer chemistry, depending on their interests and the kind of work they wish to do. For example, those interested in doing drug research in the pharmaceutical industry usually develop a strong background in synthetic organic chemistry. However, students normally need not specialize at the undergraduate level. In fact, undergraduates who are broadly trained have more flexibility when job hunting or changing jobs than if they narrowly define their interests. Most employers provide new graduates additional training or education.

In government or industry, beginning chemists with a bachelor's degree work in quality control, perform analytical testing, or assist senior chemists in research and development laboratories. Many employers prefer chemists and material scientists with a Ph.D. or at least a master's degree to lead basic and applied research. Nonetheless, relevant work experience is an asset. Chemists who hold a Ph.D. and have previous industrial experience may be particularly attractive to employers because such people are more likely to understand the complex regulations that apply to the pharmaceutical industry. Within materials science, a broad background in various sciences is preferred. This broad base may be obtained through degrees in physics, engineering, or chemistry. While many companies prefer hiring Ph.D.'s, many materials scientists have bachelor's and master's degrees. Additionally, both chemists and materials scientists need the ability to apply basic statistical techniques.

### Job Outlook

Employment of chemists is expected to grow about as fast as the average for all occupations through 2010. Job growth will be concentrated in drug manufacturing and in research, development, and testing services firms. The chemical industry, the major employer of chemists, should face continued demand for goods such as new and better pharmaceuticals and personal care products, as well as for more specialty chemicals designed to address specific problems or applications. To meet these demands, chemical firms will continue to devote money to research and development—through in-house teams or outside contractors—spurring employment growth of chemists. Strong demand is expected for chemists with a master's or Ph.D. degree.

Within the chemical industry, job opportunities are expected to be most plentiful in pharmaceutical and biotechnology firms. Biotechnological research, including studies of human genes, continues to offer possibilities for the development of new drugs and products to combat illnesses and diseases which have previously been unresponsive to treatments derived by traditional chemical processes. Stronger competition among drug companies and an aging population are contributing to the need for innovative and improved drugs discovered through scientific research. Chemical firms that develop and manufacture personal products such as toiletries and cosmetics must continually innovate and develop new and better products to remain competitive. Additionally, as the population grows and becomes better informed, the demand for different or improved grooming products—including vegetable-based products, products with milder formulas, treatments for aging skin, and products that have been developed using more benign chemical processes than in the past—will remain strong, spurring the need for chemists.

In most of the remaining segments of the chemical industry, employment growth is expected to decline as companies downsize and turn to outside contractors to provide specialized services. As a result, research and testing firms will experience healthy growth. To control costs, some chemical companies, including drug manufacturers, are increasingly turning to these firms to perform specialized research and other work formerly done by in-house chemists. Despite downsizing, some job openings will result from the need to replace chemists who retire or otherwise leave the labor force. Quality control will continue to be an important issue in the chemical and other industries that use chemicals in their manufacturing processes. Chemists also will be needed to develop and improve the technologies and processes used to produce chemicals for all purposes, and to monitor and measure air and water pollutants to ensure compliance with local, State, and Federal environmental regulations.

Environmental research will offer many new opportunities for chemists and materials scientists. To satisfy public concerns and to comply with government regulations, the chemical industry will continue to invest billions of dollars each year for technology that reduces pollution and cleans up existing waste sites. Chemists also are needed to find ways to use less energy and to discover new sources of energy.

During periods of economic recession, layoffs of chemists may occur—especially in the industrial chemicals industry. This industry provides many of the raw materials to the auto manufacturing and construction industries, both of which are vulnerable to temporary slowdowns during recessions.

### Earnings

Median annual earnings of chemists in 2000 were \$50,080. The middle 50 percent earned between \$37,480 and \$68,240. The lowest 10 percent earned less than \$29,620, and the highest 10 percent earned more than \$88,030. Median annual earnings in the industries employing the largest numbers of chemists in 2000 were:

Federal Government .....	\$65,950
Drugs .....	50,820
Research and testing services .....	41,820

A survey by the American Chemical Society reports that the median salary of all their members with a bachelor's degree was \$55,000 a year in 2000; with a master's degree, \$65,000; and with a Ph.D., \$82,200. Median salaries were highest for those working in private industry; those in academia earned the least. According to an ACS survey of recent graduates, inexperienced chemistry graduates with a bachelor's degree earned a median starting salary of \$33,500 in 2000; with a master's degree, \$44,100; and with a Ph.D., \$64,500. Among bachelor's degree graduates, those who had completed internships or had other work experience while in school commanded the highest starting salaries.

In 2001, chemists in nonsupervisory, supervisory, and managerial positions in the Federal Government averaged \$70,435 a year.

### Related Occupations

The research and analysis conducted by chemists and materials scientists is closely related to work done by agricultural and food scientists, biological and medical scientists, chemical engineers, materials engineers, physicists, and science technicians.

### Sources of Additional Information

General information on career opportunities and earnings for chemists is available from:

- American Chemical Society, Education Division, 1155 16th St. NW., Washington, DC 20036. Internet: <http://www.acs.org>

Information on obtaining a position as a chemist with the Federal Government is available from the Office of Personnel Management (OPM) through a telephone-based system. Consult your telephone directory under U.S. Government for a local number or call (912) 757-3000; Federal Relay Service: (800) 877-8339. The first number is not tollfree, and charges may result. Information also is available from the OPM Internet site: <http://www.usajobs.opm.gov>.

For general information on materials science, contact:

► Materials Research Society (MRS), 506 Keystone Dr., Warrendale, PA 15086-7573. Internet: <http://www.mrs.org>

## Environmental Scientists and Geoscientists

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### Significant Points

- Work at remote field sites is common.
- A bachelor's degree in geology or geophysics is adequate for entry-level jobs; better jobs with good advancement potential usually require at least a master's degree.
- A Ph.D. degree is required for most research positions in colleges and universities and in government.

### Nature of the Work

Environmental scientists and geoscientists use their knowledge of the physical makeup and history of the Earth to locate water, mineral, and energy resources; protect the environment; predict future geologic hazards; and offer advice on construction and land use projects.

*Environmental scientists* conduct research to identify and abate or eliminate sources of pollutants that affect people, wildlife, and their environments. They analyze and report measurements and observations of air, water, soil, and other sources to make recommendations on how best to clean and preserve the environment. They often use their skills and knowledge to design and monitor waste disposal sites, preserve water supplies, and reclaim contaminated land and water to comply with Federal environmental regulations.

*Geoscientists* study the composition, structure, and other physical aspects of the Earth. By using sophisticated instruments and analyses of the earth and water, geoscientists study the Earth's geologic past and present in order to make predictions about its future. For example, they may study the Earth's movements to try to predict when and where the next earthquake or volcano will occur and the probable impact on surrounding areas to minimize the damage. Many geoscientists are involved in the search for oil and gas, while others work closely with environmental scientists in preserving and cleaning up the environment.

Geoscientists usually study, and are subsequently classified in, one of several closely related fields of geoscience, including geology, geophysics, and oceanography. *Geologists* study the composition, processes, and history of the Earth. They try to find out how rocks were formed and what has happened to them since formation. They also study the evolution of life by analyzing plant and animal fossils. *Geophysicists* use the principles of physics, mathematics, and chemistry to study not only the Earth's surface, but also its internal composition; ground and surface waters; atmosphere; oceans; and its magnetic, electrical, and gravitational forces. *Oceanographers* use their knowledge of geology and geo-

physics, in addition to biology and chemistry, to study the world's oceans and coastal waters. They study the motion and circulation of the ocean waters and their physical and chemical properties, and how these properties affect coastal areas, climate, and weather.

Geoscientists can spend a large part of their time in the field identifying and examining rocks, studying information collected by remote sensing instruments in satellites, conducting geological surveys, constructing field maps, and using instruments to measure the Earth's gravity and magnetic field. For example, they often perform seismic studies, which involve bouncing energy waves off buried rock layers, to search for oil and gas or understand the structure of subsurface rock layers. Seismic signals generated by earthquakes are used to determine the earthquake's location and intensity.

In laboratories, geologists and geophysicists examine the chemical and physical properties of specimens. They study fossil remains of animal and plant life or experiment with the flow of water and oil through rocks. Some geoscientists use two- or three-dimensional computer modeling to portray water layers and the flow of water or other fluids through rock cracks and porous materials. They use a variety of sophisticated laboratory instruments, including x ray diffractometers, which determine the crystal structure of minerals, and petrographic microscopes, for the study of rock and sediment samples.

Geoscientists working in mining or the oil and gas industry sometimes process and interpret data produced by remote sensing satellites to help identify potential new mineral, oil, or gas deposits. Seismic technology also is an important exploration tool. Seismic waves are used to develop a three-dimensional picture of underground or underwater rock formations. Seismic reflection technology may also reveal unusual underground features that sometimes indicate accumulations of natural gas or petroleum, facilitating exploration and reducing the risks associated with drilling in previously unexplored areas.

Numerous subdisciplines or specialties fall under the two major disciplines of geology and geophysics that further differentiate the type of work geoscientists do. For example, *petroleum geologists* explore for oil and gas deposits by studying and mapping the subsurface of the ocean or land. They use sophisticated geophysical instrumentation, well log data, and computers to interpret geological information. *Engineering geologists* apply geologic principles to the fields of civil and environmental engineering, offering advice on major construction projects and assisting in environmental remediation and natural hazard reduction projects. *Mineralogists* analyze and classify minerals and precious stones according to composition and structure and study their environment in order to find new mineral resources. *Paleontologists* study fossils found in geological formations to trace the evolution of plant and animal life and the geologic history of the Earth. *Stratigraphers* study the formation and layering of rocks to understand the environment in which they were formed. *Volcanologists* investigate volcanoes and volcanic phenomena to try to predict the potential for future eruptions and possible hazards to human health and welfare.

Geophysicists may specialize in areas such as geodesy, seismology, or magnetic geophysics. *Geodesists* study the size and shape of the Earth, its gravitational field, tides, polar motion, and rotation. *Seismologists* interpret data from seismographs and other geophysical instruments to detect earthquakes and locate earthquake-related faults. *Geochemists* study the nature and distribution of chemical elements in ground water and Earth materials. *Geomagnetists* measure the Earth's magnetic field and use measurements taken over the past few centuries to devise theoretical models to explain the Earth's origin. *Paleomagnetists* interpret fossil magnetization in rocks and sediments from the continents and oceans, to record the