خلاصه کوتاهی از مهندسی شیمی

- مهندسی شیمی از کاربرد های صنعتی شیمی و علوم جدا سازی (مطالعه جداسازی ترکیب ها از مخلوطها) رشد و تکامل یافت.
- این صنایع نخست در پالایش و صنایع شیمیایی گسترش یافت که آن ها را صنایع شیمیایی می نامیم. **chemical process industries (CPI)**
- نخستین فرایند شیمیایی در مقیاس گسترده در انگلستان در سال ۱۸۲۳ برای تولید سدیم کربنات انجام شد که فراورده حاصل برای تولید شیشه و صابون بکار می رفت.
- در همان زمان، پیشرفت و توسعه فرایندهای شیمیایی به تولید رنگ های صنعتی منتهی شد که در صنایع نساجی بکار می رفت از دهه ۱۸۵۰ آغاز شد.
- نیمه دوم سده ۱۸۰۰، فرایندهای شیمیایی متعددی به صورت صنعتی در انگلستان و دیگر کشورها اجرا شد.

- در سال ۱۸۸۷، سلسله سخنرانی هایی در باره مهندسی شیمی در انگلستان ارایه شد که عملیات صنعتی انجام شده در صنایع شیمیایی را بیان می کرد.
- این سخنانی ها یه جورایی علاقه در ایالات متحده نسبت به مهندسی شیمی ایجاد کرد و تا حدی ادامه یافت که به تشکیل نخستین برنامه درسی رشته مهندسی شیمی در دانشگاه MIT در سال ۱۸۸۸ منتهی شد.
- در ۱۰-۱۵ سال پس از آن، تداد زیادی از دانشگاههای امریکا رشته مهندسی شیمی را ارایه دادند.
- در سال ۱۹۰۸، جامعه مهندسین شیمی امریکا تاسیس شد که از ان زمان تاکنون هدایت جامعه مهندسی شیمی را برعهده دارد.

- مهندسین مکانیک، جنبه های مکانیکی عملیات فرایندی از جمله جریان سیال و انتقال حرارت را خوب می دانستند ولی با شیمی آشنایی نداشتند.
- از سوی دیگر، شیمی دان ها، شیمی را می دانشتند و می توانستند نتایج واکنش ها را پیش بینی کنند ولی مهارت های فرایندی نداشتند.
- افزون برآن، نه مندسین مکانیک و نه شیمیست ها، دانشی قوی در جداسازی ترکیب ها که در صنعت بسیار مهم است نداشتند
- در ایالات متحده، تعداد کمی از دپارتمان های شیمی، مهندسین فرایند را با مدرک شیمی صنعتی تربیت کردند و همین الگویی شد تا این رشته گسترش یابد.
- با رشد برنامه درسی رشته شیمی صنعتی، این رشته بعنوان رشته مهندسی شیمی به صورت مستقل در آمد که امروزه در دانشگاههای جهان وجود دارد.

- با جاافتادن اتومبیل horseless carriage که تولید تجاری آن در سال ۱۸۹۰ آغاز شد، نیاز به بنزین به عنوان سوخت افزایش یافت که سبب گسترش استخراج نفت خام، پالایش آن و تولید سوخت شد.
- در سال ۱۹۰۱، یک زمین شناس اهل تگزاس و یک مهندس معدن، شروع به عملیات حفاری را آغاز کردند. حفاری و در نتیجه اکتشاف نفت و گسترش تولید نفت خام سبب نیاز به مجتمع های پالایشگاهی و پتروشیمیایی شد. در نتیجه این پیشرفت، شغل ها و فعالیت های مهندسی گسترش یافت که می توانستند در طراحی و عملیات کارخانه های فرایندهای شیمیایی کارکنند.
- بخشی از موفقیت اکتشاف نفت، مدیون نیاز صنعت خودروسازی به بنزین است اما در نهایت موفقیت اکتشاف نفت و صنایع پالایشگاهی منجر به تولید و رشد بسیار زیاد صنایع خودروسازیبرای عمموم مردم شد که از بهای کم بنزین تولیدی از نفت خام بهره می گیرند.

- نخستین گروه های شیمی صنعتی و مهندسین شیمی ابزارهای تجزیه ای کمی داشتند و برای انجام کارهایشان بیشتر به فعالیت های مهندسی وابسته بودند
- در دهه های ۱۹۳۰ و ۱۹۴۰، تعدادی nomograph توسعه یافت که در طراحی فرایندهای شیمیایی بکار می رفت. Nomograph نمودارهایی بودند که به صورت مختصر ابزارهایی به شمار می امدند که اطلاعات زیادی در مورد خواص فیزیکی (مانند دمای نقطه جوش یا گرمای تبخیر) فراهم می کردند
- همچنین در حل مسایل پیچیده مهندسی نیز سودمند بودند.

- منابع محاسباتی کامپیوتری از دهه ۱۹۶۰ آغازی برای طراحی فرایندها با کمک کامپیوتر بود که امروزه همه جا گسترده شده است
- برای نمونه از دهه ۱۹۷۰، پکیج های طراحی کامپیوتری به مهندسین شیمی کمک کرده است تا با کمترین اطلاعات بتوانند فرایندهای دشوار صنعتی را طراحی کنند و همه محاسبات دشوار و کشنده با کمک کامپیوتر و در زمان کوتاهی انجام می شود.

- During the period 1960 to1980, the CPI also made the transition from an industry based on innovation, in which the profitability of a company depended to a large degree on developing new products and new processing approaches, to a more mature commodity industry, in which the financial success of a company depended on making products using established technology more efficiently, resulting in less expensive products.
- Globalization of the CPI markets began in the mid-1980s and led to increased competition. At the same time, developments in computer hardware made it possible to apply process automation (advanced process control, or APC, and optimization) more easily and reliably than ever before. These automation projects provided improved product quality while increasing production rates and overall production efficiency with relatively little capital investment. Because of these economic advantages, APC became widely accepted by industry over the next 15 years and remains an important factor for most companies in the CPI.

- Beginning in the mid-1990s, new areas came on the scene that took advantage of the fundamental skills of chemical engineers, including the microelectronics industry, the pharmaceutical industry, the biotechnology industry, and, more recently, nanotechnology. Clearly, the analytical skills and the process training made chemical engineers ideal contributors to the development of the production operations for these industries. In the 1970s, over 80% of graduating chemical engineers took jobs with the CPI industry and government. By 2000, that number had dropped to 50% because of increases in the number taking jobs with biotechnology companies, pharmaceutical/health care companies, and microelectronics and materials companies. The next section addresses the current distribution of jobs for chemical engineers.

Where Do Chemical and Bioengineers Work?

Table 1.1, which lists the percentages of all chemical engineers by employment sector between 1996 and 2007, shows that the percentage of chemical engineers in these developing industries (pharmaceutical, biomedical, and microelectronic

Table 1.1. Chemical Engineering Employment by Sector (from AIChE Surveys)

	1996	2000	2002	2005	2007
Chemical, industrial gases, rubber, soaps, fibers, glass, metals, paper	33.3	32.5	25.2	28.1	25.5
Food, ag products, ag chemical	4.5	5.1	5.6	5.7	5.0
Energy, petroleum, utilities	14.1	1.9	5.1	4.5	3.7
Electronics, materials, computers	1.4	1.9	5.1	4.5	3.7
Equipment design and construction	13.8	12.6	10.6	12.6	14.3
Environmental, health, and safety	6.4	4.7	4.4	4.2	3.4
Aerospace, automobile	1.1	0.9	1.8	2.0	2.1
Research and development	3.9	3.8	4.4	4.2	3.4
Government	3.6	3.6	3.5	3.7	4.4
Biotechnology	1.5	2.2	2.4	4.4	3.7
Pharmaceutical, health care	4.2	6.5	6.1	8.4	7.6
Professional (including education)	4.7	4.5	8.6	7.0	8.4
Other	7.4	8.6	9.6	-	1.5

- Chemical engineers are first and foremost process engineers. That is, chemical engineers are responsible for the design and operation of processes that produce a wide range of products from gasoline to plastics to composite materials to synthetic fabrics to computer chips to corn chips. In addition, chemical engineers work for environmental companies, government agencies including the military, law firms, and banking companies.
- The trend of chemical engineering graduates taking employment in industries that can be designated as bioengineering is a new feature of the twenty-first century. Not only have separate bioengineering or biomedical departments been established, but some long-standing chemical engineering departments have modified their names to “chemical and bioengineering” to reflect the research and fresh interests of students and faculty.

- A bioengineer uses engineering expertise to analyze and solve problems in chemistry, biology, and medicine. The bioengineer works with other engineers as well as physicians, nurses, therapists, and technicians. Biomedical engineers may be called upon in a wide range of capacities to bring together knowledge from many technical sources to develop new procedures, or to conduct research needed to solve problems in areas such as drug delivery, body imaging, biochemical processing, innovative fermentation, bioinstrumentation, biomaterials, biomechanics, cellular tissue and genetics, system physiology, and so on. They work in industry, hospitals, universities, and government regulatory agencies. It is difficult to find valid surveys of specific companies or topics to classify bioengineering graduates' ultimate locations, but roughly speaking, one-third of graduates go to medical school, one-third continue on to graduate school, and one-third go to work in industry with a bachelor's degree.

- **1.4. Future Contributions of Chemical and Bioengineering**
- The solution of many of the pressing problems of society for the future (e.g., global warming, clean energy, manned missions to Mars) will depend significantly on chemical and bioengineers. In order to more fully explain the role of chemical and bioengineers and to illustrate the role of chemical and bioengineers in solving society's technical problems, we will now consider some of the issues associated with carbon dioxide capture and sequestration, which is directly related to global warming.
- Because fossil fuels are less expensive and readily available, we would like to reduce the impact of burning fossil fuels for energy, but without significantly increasing the costs. Therefore, it is imperative that we develop low-cost CO_2 capture and sequestration technologies that will allow us to do that.
- An examination of Figure 1.1 shows the sources of CO_2 emissions in the United States. What category would you attack first? Electric power generation is the number-one source. Transportation sources are widely distributed. No doubt power generation would be the most fruitful.

Carbon capture and storage (CCS) is viewed as having promise for a few decades as an interim measure for reducing atmospheric carbon emissions relatively quickly and sharply while allowing conventional coal-fired power plants to last their full life cycles. But the energy costs, the disposal challenges, and the fact that adding CCS to an existing plant actually boosts the overall consumption of fossil fuels (because of the increased consumption of energy to collect and sequester CO_2, more power plants have to be built so that the final production of net energy is the same) all suggest that CCS is not an ultimate solution.

One interim measure under serious consideration for CCS that might allow existing conventional coal-fired power plants to keep producing until they can be phased out at the end of their full lives involves various known technologies. An existing plant could be retrofitted with an amine scrubber to capture 80% to 95% of CO_2 from combustion gases; the CO_2 would then be condensed into a liquid that would be transported and stored somewhere indefinitely where it could not leak into the atmosphere. If several hundreds or thousands of CCS systems were deployed globally this century, each capturing 1 to 5 metric tons of CO_2 per year collectively, they could contribute between 15% and 55% of the worldwide cumulative mitigation effort.

- However, the engineering challenges are significant. First, CCS is an energy-intensive process, so power plants require significantly more fuel to generate each kilowatt-hour of electricity produced for consumption. Depending on the type of plant, additional fuel consumption ranges from 11% to 40% more—meaning not only in dollars, but also in additional fossil fuel that would have to be removed from the ground to provide the power for the capture and sequestration, as well as additional CO_2 needing sequestration by doing so. Current carbon-separation technology can increase the price tag of producing electricity by as much as 70%. Put another way, it costs about $40 to $55 per ton of carbon dioxide. The annual U.S. output of carbon dioxide is nearly 2 billion tons, which indicates the economic scale of the problem. The U.S. Department of Energy is working on ways to reduce the expenses of separation and capture.
- By far, the most cost-effective option is partnering CCS not with older plants, but with advanced coal technologies such as integrated-gasification combined-cycle (IGCC) or oxygenated-fuel (oxyfuel) technology. There is also a clear need to maximize overall energy efficiency if CCS itself is not merely going to have the effect of nearly doubling both demand for fossil fuels and the resultant CO_2 emitted.

- Once the CO_2 has been captured as a fairly pure stream, the question is what to do with it that is economical. In view of the large quantity of CO_2 that must be disposed of, disposal, to be considered a practical strategy, has to be permanent.
- Any release of gas back into the atmosphere not only would negate the environmental benefits, but it could also be deadly. In large, concentrated quantities, carbon dioxide can cause asphyxiation. Researchers are fairly confident that underground storage will be safe and effective.
- This technology, known as carbon sequestration, is used by energy firms as an oil-recovery tool. But in recent years, the Department of Energy has broadened its research into sequestration as a way to reduce emissions. And the energy industry has taken early steps toward using sequestration to capture emissions from power plants.
- Three sequestration technologies are actively being developed: storage in saline aquifers in sandstone formations [refer to S. M. Benson and T. Surles, “Carbon Dioxide Capture and Storage,” *Proceed. IEEE*, **94**, 1795 (2006)], where the CO_2 is expected to mineralize into carbonates over time; injection into deep, uneconomic coal seams; and injection into depleted or low-producing oil and natural-gas reservoirs.

- Preliminary tests show that contrary to expectations, only 20% maximum of CO_2 precipitates form carbonate minerals, but the majority of the CO_2 dissolves in water. Trapping CO_2 in minerals would be more secure, but CO_2 dissolved in brine is an alternate disposal outcome.
- Other suggestions for the reduction of CO_2 emissions include permanent reduction in demand, chemical reaction, various solvents, use of pure O_2 as the oxidant, and so on. See J. Ciferno et al., *Chemical Engineering Progress*, 33–41 (April, 2009), and F. Princiotta, “Mitigating Global Climate Change through Power-Generation Technology,” *Chemical Engineering Progress*, 24–32 (November, 2007), who have a large list of possible avenues of approach. The bottom line is that a solution for CO_2 emissions reduction is not just a matter of solving technical problems but a matter of cost and environmental acceptance. Based on the nature of these challenges, it is easy to see that chemical and bioengineers will be intimately involved in these efforts to find effective solutions.

- **1.5. Conclusion**
- The chemical engineering profession evolved from society’s need for products and energy. Today and into the future, chemical and bioengineers will continue to meet society’s needs using their process knowledge, their knowledge of fundamental science, and their problem-solving skills.