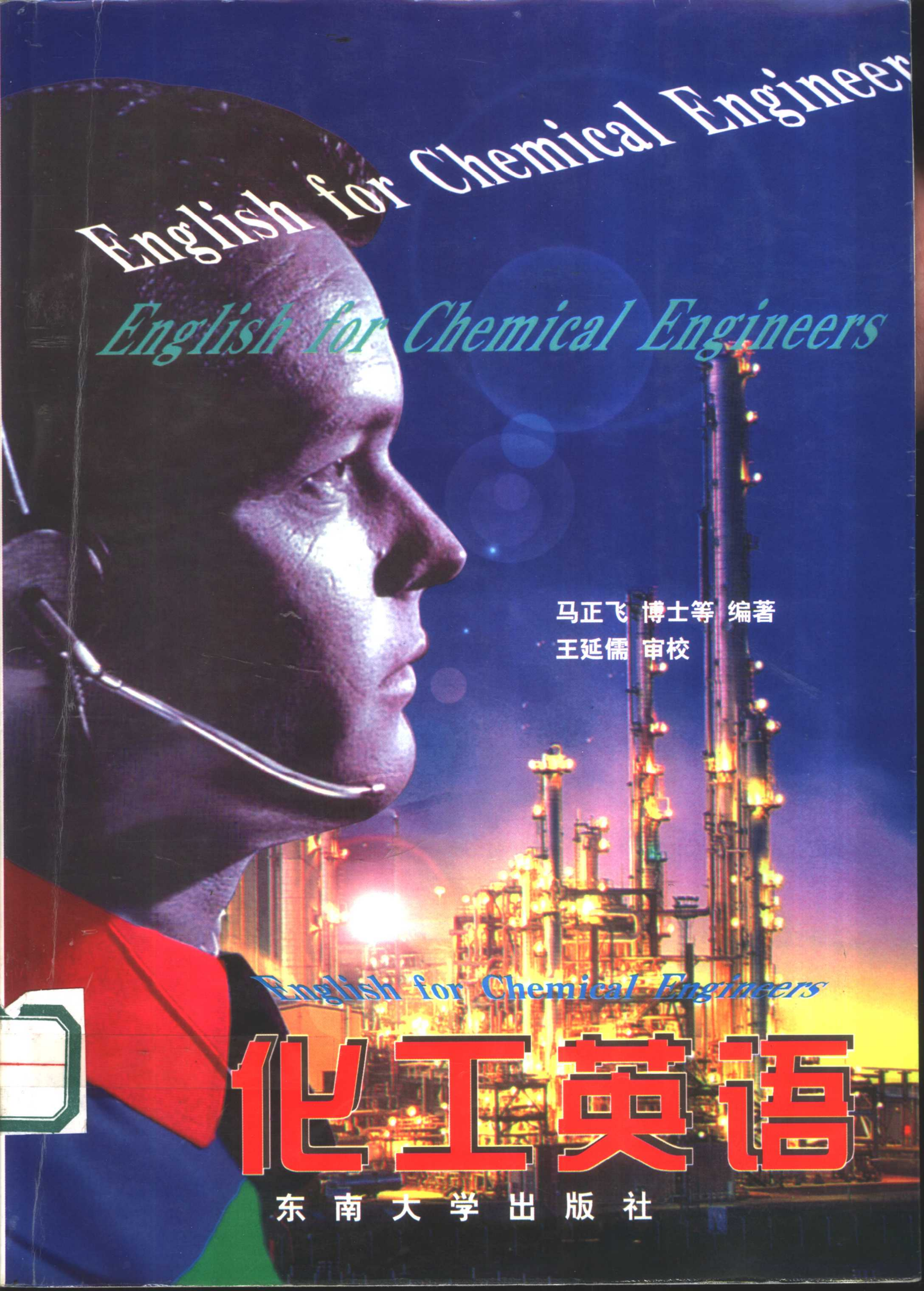

English for Chemical Engineers

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马正飞 博士等 编著

王延儒 审校

English for Chemical Engineers

化工英语

东南大学出版社

图书在版编目(CIP)数据

化工英语/马正飞编著．-南京:东南大学出版社,1999.4
(大学专业英语丛书)
ISBN 7-81050-455-X

Ⅰ．化… Ⅱ．马… Ⅲ．化学工业-英语-高等学校-教材
Ⅳ．H31

中国版本图书馆 CIP 数据核字(1999)第 11620 号

东南大学出版社出版发行
(南京四牌楼 2 号 邮编 210096)
出版人:洪焕兴
江苏省新华书店经销 南京邮电学院印刷厂印刷
开本:787mm×1092mm 1/16 印张:14 字数:324 千字
1999 年 5 月第 1 版 1999 年 5 月第 1 次印刷
印数:1～3000 定价:18.00 元

序

《化工英语》是根据全国高等院校理工科大学英语教学大纲精神，并按照最新的化学工程与技术一级学科的涵盖范围收集材料编写而成的。全书分为九个单元，内容涉及化学工程、单元操作、传质分离、化学工艺、生物化工、应用化学、工业催化、反应工程，以及计算机模拟与设计等学科分支。对于科技工作者而言，英语是不可或缺的有用工具，不少学生在走上工作岗位后常感词汇量尤其是专业词汇量缺乏。对此，除了广泛阅读与本专业有关的题材外，并无其他捷径。有鉴于此，本书在每一讲课文后均有一篇阅读材料作为补充，并在附录中增添化学与化工的期刊和化工与技术常用术语，以供学习参考。相信在学完本书后，可在专业词汇积累和阅读书刊能力方面得到强化。

本书可作为化工类各专业高年级学生专业英语教材，也可作为其他科技人员的自学用书。

由于我们水平有限，疏漏之处，敬请读者不吝指正。

编者

1999 年 3 月

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Unit One
General Chemical Engineering

Lesson 1

Chemical Engineering

Chemical engineering is the development of processes and the design and operation of plants in which materials undergo changes in physical or chemical state on a technical scale. Applied throughout the process industries, it is founded on the principles of chemistry, physics, and mathematics. The laws of physical chemistry and physics govern the practicability and efficiency of chemical engineering operations. Energy changes, deriving from thermodynamic considerations, are particularly important. Mathematics is a basic tool in optimization and modeling. Optimization means arranging materials, facilities, and energy to yield as productive and economical an operation as possible. Modeling is the construction of theoretical mathematical prototypes of complex process systems, commonly with the aid of computers.

Chemical engineering is as old as the process industries. Its heritage dates from the fermentation and evaporation processes operated by early civilizations. Modern chemical engineering emerged with the development of large-scale, chemical-manufacturing operations in the second half of the 19th century. Throughout its development as an independent discipline, chemical engineering has been directed toward solving problems of designing and operating large plants for continuous production.

Manufacture of chemicals in the mid-19th century consisted of modest craft operations. Increase in demand, public concern at the emission of noxious effluents, and competition between rival processes provided the incentives for greater efficiency. This led to the emergence of combines with resources for larger operations and caused the transition from a craft to a science-based industry. The result was a demand for chemists with knowledge of manufacturing processes, known as industrial chemists or chemical technologists. The term chemical engineer was in general use by about 1900. Despite its emergence in traditional chemicals manufacturing, it was through its role in the development of the petroleum industry that chemical engineering became firmly established as a unique discipline. The demand for plants capable of operating physical separation processes continuously at high levels of efficiency was a challenge that could not be met by the traditional chemist or mechanical engineer.

A landmark in the development of chemical engineering was the publication in 1901 of the first textbook on the subject, by George E. Davis, a British chemical consultant. This concentrated on the design of plant items for specific operations. The notion of a processing plant encompassing a number of operations, such as mixing, evaporation, and filtration, and of these operations being essentially similar, whatever the product, led to the concept of unit operations[1]. This was first enunciated by the American chemical engineer Arthur D. Little in 1915 and formed the basis for a classification of chemical engineering that dominated the subject for the next 40 years. The number of unit operations — the building blocks of a chemical plant — is not large. The complexity arises from the variety of conditions under which the unit operations are conducted.

In the same way that a complex plant can be divided into basic unit operations, so chemical reactions involved in the process industries can be classified into certain groups, or unit processes (e.g., polymerizations, esterifications, and nitrations), having common characteristics[2]. This classification into unit processes brought rationalization to the study of process engineering.

The unit approach suffered from the disadvantage inherent in such classifications: a restricted outlook based on existing practice. Since World War II, closer examination of the fundamental phenomena involved in the various unit operations has shown these to depend on the basic laws of mass transfer, heat transfer, and fluid flow. This has given unity to the diverse unit operations and has led to the development of chemical engineering science in its own right; as a result, many applications have been found in fields outside the traditional chemical industry.

Study of the fundamental phenomena upon which chemical engineering is based has necessitated their description in mathematical form and has led to more sophisticated mathematical techniques[3]. The advent of digital computers has allowed laborious design calculations to be performed rapidly, opening the way to accurate optimization of industrial processes. Variations due to different parameters, such as energy source used, plant layout, and environmental factors, can be predicted accurately and quickly so that the best combination can be chosen[4].

Chemical Engineering Functions. Chemical engineers are employed in the design and development of both processes and plant items. In each case, data and predictions often have to be obtained or confirmed with pilot experiments. Plant operation and control is increasingly the sphere of the chemical engineer rather than the chemist. Chemical engineering provides an ideal background for the economic evaluation of new projects and, in the plant construction sector, for marketing.

Branches of Chemical Engineering. The fundamental principles of chemical engineering underlie the operation of processes extending well beyond the boundaries of the chemical industry, and chemical engineers are employed in a range of operations outside traditional areas. Plastics, polymers, and synthetic fibers involve chemical reaction engineering problems in their manufacture, with fluid flow and heat transfer considerations dominating their fabrication[5]. The dyeing of a fiber is a mass-transfer problem. Pulp and paper manufactures involve considerations of fluid flow and heat transfer. While the scale and materials are different, these again are found in modern continuous production of foodstuffs. The pharmaceuticals industry presents chemical engineering problems, the solutions of which have been essential to the availability of modern drugs. The nuclear industry makes similar demands on the chemical engineer, particularly for fuel manufacture and reprocessing. Chemical engineers are involved in many sectors of the metals processing industry, which extends from steel manufacture to separation of rare metals[6].

Further applications of chemical engineering are found in the fuel industries. In the second half of the 20th century, considerable numbers of chemical engineers have been involved in space exploration, from the design of fuel cells to the manufacture of propellants[7]. Looking to the future, it is probable that chemical engineering will provide the solution to at least two of the world's major problems: supply of adequate fresh water in all regions through desalination of seawater and environmental control through prevention of pollution.

(C. Ha and C. Hanson)

New Words

1. thermodynamics [ˈθəməudaiˈnæmiks] *n.* 热力学
2. prototype [ˈprəutətaip] *n.* 原型，主型
3. heritage [ˈheritidʒ] *n.* 遗产，继承物
4. manufacture [mænjuˈfæktʃə] *n.* 产品，制造
5. emergence [iˈməːdʒəns] *n.* 出现，浮现
6. craft [kræft] *n.* 手艺，技艺
7. enunciate [iˈnʌnsieit] *v.* 明确叙述
8. rationalization [ˈræʃənəlaiˈzeiʃən] *n.* 合理化
9. foodstuff [ˈfuːdstʌf] *n.* 食品，粮食
10. desalination [disɔːliˈneiʃən] *n.* 脱盐
11. pollution [pəˈluːʃən] *n.* 污染

Notes

1. The notion of a processing plant encompassing a number of operations, such as mixing, evaporation, and filtration, and of these operations being essentially similar, whatever the product, led to the concept of unit operations. 注意到加工厂包括的一系列操作，如混合、蒸发、过滤，无论产物是什么，这些操作都基本相同，从而导致了单元操作的概念。
2. In the same way that a complex plant can be divided into basic unit operations, so

chemical reactions involved in the process industries can be classified into certain groups, or unit processes (e.g., polymerizations, esterifications, and nitrations), having common characteristics. 同复杂的工厂可划分为基本的单元操作一样，过程工业中涉及的化学反应也可分成为一定的单元过程(如聚合、酯化和硝化)，它们具有共同的特性。本句中，group 和 unit process 具有相同含义，前者为普通用词，后者为科技用词。在科技文章中，常有此种情况出现，注意此类现象，可帮助理解。

3. Study of the fundamental phenomena upon which chemical engineering is based has necessitated their description in mathematical form and has led to more sophisticated mathematical techniques. 研究化工依赖的基本现象需采用数学形式来描述，并借助复杂的数学技术来解决。
4. Variations due to different parameters, such as energy source used, plant layout, and environmental factors, can be predicted accurately and quickly so that the best combination can be chosen. 如所用的能量来源、工厂布置和环境因素这样的不同参数引起的变化可正确和快速地得到预测，就可能选择出最佳的组合。
5. Plastics, polymers, and synthetic fibers involve chemical reaction engineering problems in their manufacture, with fluid flow and heat transfer considerations dominating their fabrication. 塑料、聚合物和合成纤维在生产中涉及化学反应工程问题，其中流体流动和传热是生产中主要考虑的因素。
6. rare metal　稀有金属，而 rare earth　稀土。
7. In the second half of the 20th century, considerable numbers of chemical engineers have been involved in space exploration, from the design of fuel cells to the manufacture of propellants. 20 世纪下半叶，从燃料电池的设计到推进剂的生产，相当数量的化学工程师参与了空间的探索。

Comprehension and Toward Interpretation

1. What are chemical engineering and its content?
2. What concept is the landmark in the development of chemical engineering?
3. What are the basic laws of chemical engineering science?
4. Name the functions and branches of chemical engineering you know.

Reading Material

What is Chemical Engineering

Society can associate civil engineers with huge new building complexes and bridges, electronic and electrical engineers with telecommunications and power generation, and mechanical engineers with advanced machinery and automobiles. However, chemical engineers have no obvious monuments which create an immediate awareness of the discipline in the public mind. Nevertheless, the range of products in daily use which are efficiently produced as a result of the application of chemical engineering expertise is enormous. The list given in Table 1 is not exhaustive, and any reader who grasps the key element, which involves the conversion of raw materials into a useful product, will be able to extend it. Although the products are unglamorous, the creation and operation of cost-effective processes to produce them is often challenging and exciting.

The term "chemical engineer" implies that the person is primarily an engineer whose first professional concern is with manufacturing processes — making something, or making some process work. The adjective "chemical" implies a particular interest in processes which involve chemical changes. While the main term is correct, the adjective is too restrictive and the literal definition will not suffice. Taken at face value, it would exclude many areas in which chemical engineers have made their mark, for example, textiles, nuclear fuels and the food industry. Thus the Institution of Chemical Engineers defines chemical engineering as "that branch of engineering which is concerned with processes in which materials undergo a required change in composition, energy content or physical state: with the means of processing; with the resulting products, and with their application to useful ends". It is perhaps too presumptuous to insist that the term "process engineer" should replace the term "chemical engineer", and so the two will be used synonymously.

It should also be noted that large-scale processes involving biological systems (such as waste water treatment and production of protein) fit the definition as well as traditional chemical processes such as the production of fertilizers and pharmaceuticals.

The work of chemical engineers will be examined by way of four case studies in the second part of this chapter, but to complete the definition, explicit mention of the concern that process operations be both safe and economic must be made.

A jocular, helpful, but very incomplete description is that, "a chemical engineer is a chemist who is aware of money". Although this neglects many, if not most, aspects of a chemical engineer's training, it does illustrate one important facet of any engineer's work. When working on a large scale, the cost of equipment and raw materials are more important than the cost of manpower. While the research chemist might use aqueous potassium hydroxide to neutralize acids, because it is pure and readily available, the chemical engineer will specify a cheaper alternative, provided that it serves the same purpose. Two obvious substitutes are aqueous sodium hydroxide, which is available at less than a tenth of the cost, or calcium hydroxide, which is even cheaper, but harder to handle. In choosing between these cheaper alternatives, an engineer has to balance the cost of handling a slurry (calcium hydroxide is sparingly soluble) against the higher price of sodium hydroxide.

Table 1 A selection of everyday products whose manufacture involves the application of chemical engineering

process Product grouping or production

1. Household products in daily use
2. Health care products
3. Automotive fuels / Petroleum refining
4. Other chemicals in daily use
5. Horticultural products
6. Metals
7. Polymerization, extrusion and molding of thermoplastics
8. Polymerization, production and spinning of synthetic fibers
9. Electronics
10. Fats and oils
11. Fermentation
12. Dairy products
13. Gas treatment and transmission

Some of the more familiar examples

1. Detergents, polishes, disinfectants
2. Pharmaceuticals, toiletries, antiseptics, anesthetics
3. Petrol, diesel, lubricants
4. Latex paints, rubber, anti-freeze, refrigerants, insulation materials
5. Fertilizers, fungicides, insecticides
6. Steel manufacture, zinc production
7. Washing-up bowls, baths, insulation for cables, road signs, children's toys
8. Clothes, curtains, sheets, blankets
9. Raw materials, silicon, gallium arsenide, etchants, dopants
10. Salad and cooking oils, margarine, soap
11. Beer; certain antibiotics such as penicillin, yoghurts
12. Milk, butter, cheese, baby food
13. Gas for heating and cooking

Lesson 2

Traditional Paradigms of Chemical Engineering

Every scientific discipline has its characteristic set of problems and systematic methods for obtaining their solution, that is, its paradigm. Chemical engineering is no exception. Since its birth in the last century, its fundamental intellectual model has undergone a series of dramatic changes.

When the Massachusetts Institute of Technology (MIT)[1] started a chemical engineering program in 1888 as an option in its chemistry department, the curriculum largely described industrial operations and was organized by specific products. The lack of a paradigm some became apparent. A better intellectual foundation was required because knowledge from one chemical industry was often different in detail to that from other industries, just as the chemistry of sulfuric acid is very different from that of lubricating oil[2].

The first paradigm for the discipline of chemical engineering was based on the unifying concept of "unit operations"[3] proposed by Arthur D. Little[4] in 1915. It evolved in[5] response to the need of economic large-scale[6] manufacture of commodity products. The concept of unit operations held that any chemical manufacturing process could be resolved into a coordinated series of operations such as pulverizing, drying, roasting, crystallizing, filtering, evaporating, distilling, electrolyzing, and so on[7]. Thus, for example, the academic study of the specific aspects of turpentine manufacture could be replaced by the genetic study of distillation, a process common to many other industries. A quantitative form of the unit operations concept emerged around 1920, just in time for the first gasoline crisis because of the rapidly growing number of automobiles. The ability of chemical engineers to quantitatively characterize unit operations such as distillation allowed for the rational design of the first modern oil refineries. The first boom of employment of chemical engineers in the oil industry was on[8].

During this period of intensive developments of unit operations, other classical tools of chemical engineering analysis were introduced or were extensively developed. These included studies of the material and energy balance of processes and fundamental thermodynamic studies of multicomponent systems.

After World War II, the gradual exhaustion of research problems in conventional unit operations was seen. This led to the rise of a second paradigm for chemical engineering, pioneered by the engineering science movement. Dissatisfied with empirical descriptions of process equipment performance, chemical engineers began to reexamine unit operations from a more fundamental point of view. The phenomena that take place in unit operations were resolved into sets of molecular events. Quantitative mechanistic models for these events were developed and used to analyze existing equipment, as well as to design new process equipment. Mathematical models of processes and reactors were developed and applied to capital-intensive industries such as commodity petrochemicals.

New Words

1. discipline [ˈdisiplin] *n.* 学科
2. systematic[sistiˈmætik] *a.* 系统的
3. paradigm[ˈpærədaim] *n.* 式样，范例
4. option [ˈɔpʃən] *n.* 选择
5. curriculum [kəˈrikjuləm] *n.* 课程
6. unifying [ˈjuːnifaiiŋ] *a.* 通用的，统一的
7. manufacture [mænjuˈfæktʃə] *n.* 制造，生产
8. commodity [kəˈmɔditi] *n.* 商品，日用品
9. resolve [riˈzɔlv] *v.* 分解，分辨
10. coordinate [kəuˈɔːdineit] *v.* (使)同等，使协调
11. turpentine [ˈtəːpəntain] *n.* 松油，松香水
12. quantitative [ˈkwɔntitətiv] *a.* 定量的 (qualitative 定性的)
13. characterize [ˈkærəktəraiz] *v.* 表征，特性描写
14. thermodynamic [θəːməudaiˈnæmik] *a.* 热力学的
15. multicomponent [ˈmʌltikəmˈpounənt] *a.* 多组分的，多元的
16. petrochemical [petrəuˈkemikəl] *n.* 石油化学品

Notes

1. The Massachusetts Institute of Technology (MIT) 美国麻省理工学院（世界最著名的理工大学之一）
2. A better intellectual foundation was required because knowledge from one chemical industry was often different in detail to that from other industries, just as the chemistry of sulfuric acid is very different from that of lubricating oil.更好的知识基础是需要的，因为来自化学工业的知识常常在细节上同其它工业的知识不同，如同硫酸的化学特性完全不同于润滑油的化学特性一样。从这句话里可看到，英语和汉语不同，英语大量使用代词，避免重复，第一个 that 代替 knowledge，第二个 that 代替 chemistry，而汉语一般都重复说。在学习科技英语时要注意这一特点。 sulfuric acid 硫酸，lubricating oil 润滑油。
3. unit operations 单元操作
4. Arthur D. Little 人名。英语名在前，姓在后，如将姓写在前面，则为 Little, Arthur D.
5. evolve in 发展(进化)成为
6. large-scale 大规模

7. The concept of unit operations held that any chemical manufacturing process could be resolved into a coordinated series of operations such as pulverizing, drying, roasting, crystallizing, filtering, evaporating, distilling, electrolyzing, and so on. 单元操作的概念认为：任何化学生产过程可分解为一系列同等的操作，如粉碎、干燥、焙烧、结晶、过滤、蒸发、蒸馏、电解等。

pulverizing 粉碎	drying 干燥	roasting 焙烧	crystallizing 结晶
filtering 过滤	evaporating 蒸发	distilling 蒸馏	electrolyzing 电解

8. The ability of chemical engineers to quantitatively characterize unit operations such as distillation allowed for the rational design of the first modern oil refineries. 化学工程师具有定量表征像精馏这样的单元操作的能力，可以合理设计第一代新型炼油厂。distillation 精馏，为一种化工单元操作，是一种多级的蒸馏(distilling)过程，注意两词的区别。蒸馏水的英文为 distilled water。

Comprehension and Toward Interpretation

1. What is the first paradigm for the discipline of chemical engineering?
2. How does the second paradigm differ from the first one?
3. What was the consequence of the second paradigm for chemical engineering?
4. According to your opinion, What are the most important aspects of chemical engineering?

Reading Material

A New Paradigm for Chemical Engineering

Over the next few years, a confluence of intellectual advances, technological challenges, and economic driving forces will shape a new model of what chemical engineering is and what chemical engineers do.

A major force behind this evolution will be the explosion of new products and materials that will enter the market during the next two decades. Whether from the biotechnology industry, the electronics industry, or the high-performance materials industry, these products will be critically dependent on structure and design at the molecular level for their usefulness. They will require manufacturing processes that can precisely control their composition and structure. These demands will create new opportunities for chemical engineers, both in product design and in process innovation.

A second force that will contribute to a new chemical engineering paradigm is the increased competition for worldwide markets. Product quality and performance are becoming more important to global competition than ever before. The key to meeting these challenges is innovation in process design, control, and manufacturing operations. It is particularly important in the commodity chemical markets.

The third force shaping the future of chemical engineering is society's increasing awareness of health risks and environmental impacts from the manufacture, transportation, sue, and ultimate disposal of chemicals. This will be an important source of new challenges to chemical engineers.

Modern society will not tolerate a continuing occurrence of such incidents as the release of methyl isocyanate at Bhopal (in 1985) and the contamination of the Rhine (in 1986). It is up to the chemical engineering profession to act as the cradle-to-grave guardian for chemicals, ensuring their safe and environmentally sound use.

The fourth and most important force in the development of tomorrow's chemical engineering is the intellectual curiosity of chemical engineers themselves. As they extend the limits of past concepts and ideas, chemical engineering researchers are creating new knowledge and tools that will profoundly influence the training and practice of the next generation of chemical engineers.

When a discipline adopts a new paradigm, exciting things happen, and the current era is probably one of the most challenging and potentially rewarding times to be entering chemical engineering. How can the unfolding pattern of change in the discipline be described?

The focus of chemical engineering has always been industrial processes that change the physical state or chemical composition of materials. Chemical engineers engage in the synthesis, design, testing, scale-up, operation, control, and optimization of these processes. The traditional level of size and complexity at which they have worked on these problems might be termed the mesoscale. Examples of this scale include reactors and equipment for single processes (unit operations) and combinations of unit operations in manufacturing plants. Future research at the mesoscale will increasingly supplemented by studies of phenomena taking place at molecular dimensions — the microscale — and the dimensions of extremely complex systems — the macroscale.

Chemical engineers of the future will be integrating a wider range of scales than any other branch of engineering. For example, some may work to relate the macroscale of environment to the mesoscale of combustion systems and the microscale of molecular reactions and transport. Others may work to relate the macroscale performance of a composite aircraft to the mesoscale chemical reactor in which the wing was formed, the design of the reactor perhaps having been influenced by studies of the microscale dynamics of complex liquids.