普通高等教育“十二五”规划教材

化工专业英语

丁丽 王志萍 编

SPECIALIZED ENGLISH FOR CHEMICAL ENGINEERING

化学工业出版社

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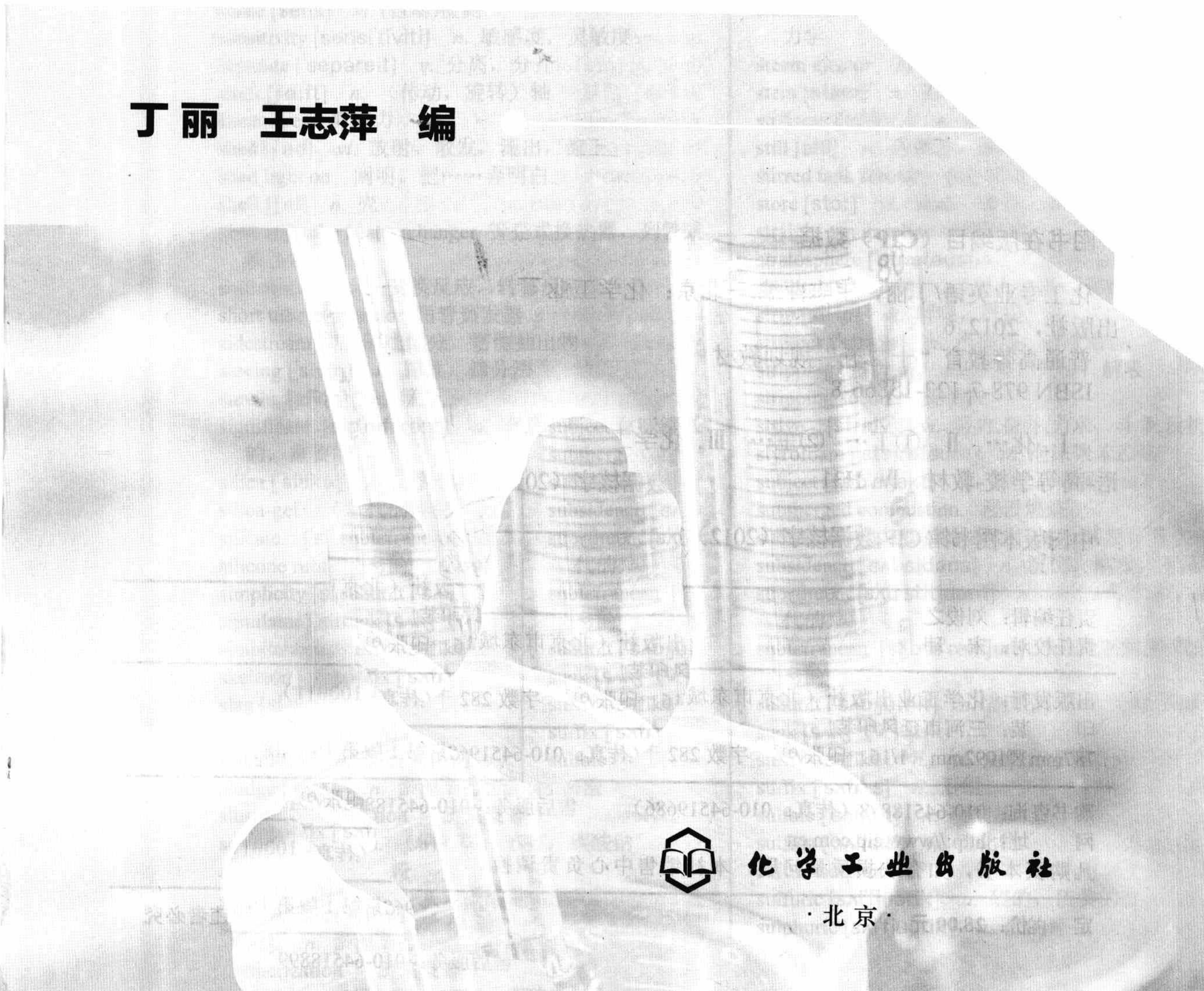

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本书是为化工及相关专业编写的专业英语教材，旨在提高学生阅读英语科技文献水平。材料来源于英文原版书籍、化工方面的杂志等。本书选材范围广、词汇全面，主要内容包括化学反应、化学工程、单元操作及最新技术等共 24 个单元。每个单元由课文、词汇表、难点注释、课后练习和阅读材料组成。文章内容丰富，语言难度适中，编排深入浅出，循序渐进。书后还附有总词汇表、化学化工常用构词、常用有机基团名称，便于读者查阅和自学。

本书可作为化工及相关专业本科、专科学生和在职硕士生的专业英语教材，化工专业高职类学生也可以选用，也可作为从事化工产品生产工作人员的参考书。

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前 言

随着社会对化工专业技术人才素质要求的提高，具备化工专业知识技能并掌握化工专业英语的技术人才越来越受到社会各界的欢迎。《化工专业英语》（Specialized English for Chemical Engineering）是化工专业学生一门非常重要的课程，着重培养学生对英文资料的阅读及写作的能力。为适应新时期对化工专业学生的能力培养目标和综合素质的要求，我们针对化工专业的学生，分析并比较众多的同类教材，博采众长，结合青岛科技大学化工专业的教学实践，编写了本书。

本书在编写时紧扣化工专业知识，从适用及专业方面考虑，突出实用、够用和好用的特点。各章节内容涵盖了化学工程的基础内容和前沿领域，主要内容包括化学反应、化学工程、单元操作及最新技术等共24个单元。每个单元由课文、词汇表、难点注释、课后练习和阅读材料组成。选材范围广、词汇全面，所选内容适应性强，覆盖面宽，图文并茂，内容丰富，适宜化工类及相关专业本、专科学生及在职研究生作为教材选用或自学。

由于编者水平有限，书中不妥之处在所难免，敬请使用本书的读者指正，不胜感激。

编　者

2012年2月

目　录

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 if 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.

Selected from "English for Chemical Engineers, by Ma Zhengfei etc., Southeast University Press, 2006, 1-4"

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 [ˌræʃənəlaiˈzeiʃən] *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. 参考译文：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., polymerization, esterifications, and nitrations), having common characteristics. 参考译文：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. 参考译文：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. 参考译文：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. 参考译文：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 metals 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. 参考译文：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。

Exercise

1. Put the following into Chinese:

thermodynamics	manufacture	craft	foodstuff
desalination	mathematics	evaporation	filtration
rare metal	telecommunication	unglamorous	definition

2. Put the following into English:

主型	出现	明确叙述	合理化
技艺	污染	单元操作	合成纤维

3. Comprehension and Toward Interpretation

a.what are chemical engineering and its content?

b.what concept is the landmark in the development of chemical engineering?

c.what are the basic laws of chemical engineering science?

d.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 1-1 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 1-1 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	

Selected from "English for Chemical Engineers, by Ma Zhengfei etc., Southeast University Press, 2006, 5-6"

Lesson 2

Chemical Equilibrium and Kinetics

A major objective of chemist is to understand chemical reactions, to know whether under a given set of conditions two substances will react when mixed, to determine whether a given reaction will be exothermic or endothermic, and to predict the extent to which a given reaction will proceed before equilibrium is established. An equilibrium state, produced as a consequence of two opposing reactions occurring simultaneously, is a state in which there is no net change as long as there is no change in conditions. In this lesson it will be shown how one predict the equilibrium state of chemical systems from thermodynamic data, and conversely how the experimental measurements states provide useful thermodynamic data. Thermodynamics alone cannot explain the rate at which equilibrium is established, nor does it provide details of the mechanism by which equilibrium is established. Such explanations can be developed from considerations of the quantum theory of molecular structure and from statistical mechanics.

To appreciate fully the nature of the chemical equilibrium state, it is necessary first to have some acquaintance with the factors which influence reaction rates. The factors which influence the rates of a chemical reaction are temperature, concentrations of reactants (or partial pressures of gaseous reactants), and presence of a catalyst. In general, for a given reaction the higher the temperature, the faster the reaction will occur. The concentrations of reactants or partial pressure of gaseous reactants will affect the rate of reaction, an increase in concentration or partial pressure increases the rate of most reactions. Substances which accelerate a chemical reaction but which themselves are not used up in the reaction are called catalysts.

Dynamic Equilibrium

In many cases, direct reactions between two substances appear to cease before all of either starting material is exhausted. Moreover, the products of chemical reactions themselves often react to produce the starting materials. For example, nitrogen and hydrogen combine at 500 ℃ in the presence of a catalyst to produce ammonia:

$$N_2 + 3H_2 = 2NH_3$$

At the same temperature and in the presence of the same catalyst, pure ammonia decomposes into nitrogen and hydrogen:

$$2NH_3 = 3H_2 + N_2$$

For convenience, these two opposing reactions are denoted in one equation by use of a double arrow:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

The reaction proceeding toward the right is called the forward reaction; the other is called the reverse reaction.

If either ammonia or a mixture of nitrogen and hydrogen is subjected to the above conditions, a mixture of all three gases will result. The rate of reaction between the materials which were introduced into the reaction vessel will decrease after the reaction starts; because their concentrations are decreasing, conversely, after the start of the reaction the material being produced will react faster, since there will be more of it. Thus the faster forward reaction becomes slower, and the slower reverse reaction speeds up. Ultimately the time comes when the rates of the forward and reverse reactions become equal, and there will be no further net change[1]. This situation is called equilibrium. Equilibrium is a dynamic state because both reactions are still proceeding; but since the two opposing reactions are proceeding at equal rates, no net change is observed.

All chemical reactions ultimately proceed toward equilibrium. In a practical sense, however, some reactions go so far in one direction that the reverse reaction cannot be detected, and they are said to go to completion. The principles of chemical equilibrium apply even to these, and it will be seen that for many of them, the extent of reaction can be expressed quantitatively[2].

Equilibrium Constants

Equilibrium is a state of dynamic balance between two opposing processes. For a general reaction at a given temperature:

$$A + B \rightleftharpoons C + D$$

At the point of equilibrium, the following ratio must be a constant:

$$K = \frac{CD}{AB}$$

The constant, *K*, is called the equilibrium constant of the reaction. It has a specific value at a given temperature. If the concentration of any of the components in the system at equilibrium is changed, the concentrations of the other components will change in such a manner that the defined ratio remains equal to *K* as long as the temperature does not change[3]. The equilibrium constant expression quantitatively defines the equilibrium state.

More generally, for the reversible reaction

$$aA + bB \rightleftharpoons cC + dD$$

the equilibrium constant expression is written as follows:

$$K = \frac{C^c D^d}{A^a B^b}$$

By convention, the concentration terms of the reaction products are always placed in the numerator of the equilibrium constant expression. It should be noted that the exponents of the concentration terms in the equilibrium constant expression are the coefficients of the respective species in the balanced chemical equation.

Chemical Kinetics

When a system is in the equilibrium state, the rate of the forward reaction is identical to the rate of the reverse reaction. It is important to know just how fast a reactant is being used up in a process, or the speed with which a product is being formed. It is also important to have detailed information about rates of reactants in order to test theories and mechanisms for various kinds of chemical processes.

Experiments show that a number of reaction variables affect reaction rates:

Temperature. The rates of chemical reactions are temperature-dependent. Therefore, it is common practice when studying the rate in the laboratory to carry out reactions at constant temperature (isothermally), thus eliminating one variable[4].

Pressure and Volume. Pressure is important in a kinetic consideration of gas phase reactions. Usually, volume is fixed by running the reaction in a container of fixed dimensions. For solid and liquid state reactions, pressure is usually atmospheric, and the volume of the reacting system is relatively unimportant because there is little change in volume.

Concentration. At any particular temperature, the rates of most chemical reactions are functions of the concentrations of one or more of the components of the system. In practice, it is usually the concentration of the reactants that are used in determining the overall rates of reaction[5].

Catalyst. Any substance that affects the rate of a chemical reaction but cannot be identified as a product or reactant is said to be a catalyst. Catalyst may accelerate the rate, but we usually refer to decelerating catalysts as inhibitors.

The order of a chemical reaction is given by the number of atomic or molecular species whose concentrations directly determine the reaction rate.

The rate of hydrolysis of acetate in water is directly proportional to the ethyl acetate concentration, the reaction is said to be first order.

Selected form "Specialized Chemical English (unformal published) (volumn two), by Cui Bo etc., 1994, 66-76"

New Words

1. kinetics [kai'netiks] *n.* 动力学
2. equilibrium state 平衡状态
3. opposing [ə'pəuziŋ] *n.* 相反，相对，反抗
4. datum ['deitəm] (复 data ['deitə]) *n.* 资料，论据
5. molecular structure 分子结构
6. quantum ['kwɔntəm] *n.* 量子
7. quantum theory 量子论
8. statistical mechanics [stə'tistikəl mi'kæniks] 统计力学
9. acquaintance [ə'kweintns] *n.* 熟悉，认识 (with)
10. partial pressure ['pɑːʃəl'preʃə] 分压
11. affect [ə'fekt] *vt.* 影响
12. accelerate [æk'seləreit] *vt.* 加速
13. dynamic [dai'næmik] *a.* 动力的
14. cease ['siːs] *v.* 停止，终止
15. forward reaction 正反应
16. reverse reaction 逆反应
17. subject [səb'dʒekt] *vt.* 遭受，蒙受（to）
18. ultimately ['ʌltimitli] *ad.* 最后，最终
19. specific value 比值
20. term [təːm] *n.* (比例或方程的)项
21. numerator ['njuːməreitə] *n.* (分数中的)分子
22. exponent [eks'pəunənt] *n.* 指数
23. coefficient ['koui'fiʃənt] *n.* 系数，率
24. test [test] *vt.* 检验，验证，试验
25. isothermal ['aisou'θəːml] *a.* 等温线的
26. decelerate [diː'seləreit] *v.* 减速，减慢
27. order ['ɔːdə] *n.* 级数
28. rate law 速度定律

Phrases

1. as a consequence of 由于……（结果）
2. as long as… 只要
3. not…, …nor 不……，也不……
4. have acquaintance with… 熟悉，认识
5. use up 消耗掉，用完
6. in a practical sense 实际上
7. in such a manner that… 以这样的方式以致……
8. by convention 按照惯例
9. it is common practice (+ inf.) 通常的做法是……
10. over-all 总的，全部的
11. an educated guess 有根据的推测
12. refer to…as… 把……称作

Notes

1. Ultimately the time comes when the rates of the forward and reverse reactions become equal, and there will be no further net change. 系主从复合句，主句是"Ultimately the time comes"，"when the rates…net change"是由 when 引导的、由 and 连接的两个并列的定语从句，它们修饰主句中的主语 the time。参考译文："最后，正反应和逆反应速率变得相等，且不再有进一步净变化的时刻终于到来"。

2. The principles of chemical equilibrium apply even to these, and it will be seen that for many of them, the extent of reaction can be expressed quantitatively. 该句为 and 连接的并列复合句，第一个分句中的 these 指上句中提到的反应，即"some reactions go so…to completion"。参考译文："化学平衡的原理甚至也适用于被认为是进行完全的反应，显然许多这类反应其反应程度可以定量地表达"。

3. If the concentration of any of the components in the system at equilibrium is changed, the concentrations of the other components will change in such a manner that the defined ratio remains equal to K as long as the temperature does not change. 系主从复合句， if 引导的是条件状语从句，主句是“the concentration of the other…句末”，主句中“in such a manner”为方式状语，“that the defined … not change”为修饰 manner 的定语从句，此定语从句中又带有一个条件状语从句，即“as long as … not change”。参考译文：“如果平衡时体系中任意组分的浓度改变，那么只要温度不变，其他组分的浓度将以保持相等 K 的固定比例的方式变化”（意译）。

4. Therefore, it is common practice when studying the rate in the laboratory to carry out reactions at constant temperature (isothermally), thus eliminating one variable. 系主从复合句，主句是“it is common practice to carry out …句末”，其中“thus eliminating one variable”是结果状语，一般 thus + 现在分词的短语在句中常表示结果。“when studying the rate in the laboratory”为时间状语。

5. In practice, it is usually the concentration of the reactants that are used in determining the overall rates of reaction. 此句是强调句型，句中强调了主语“the concentration of the reactions”。参考译文：“实际上，一般正是反应物的浓度用以测定反应的总速度”。

Exercise

1. Put the following into Chinese:

kinetics	forward reaction	use up	correlation
opposing	numerator	distinguish	behaviour
accelerate	isothermal	acquaint	vital

2. Put the following into English:

平衡态	分压	系数	雷诺数
量子	动力学	受益	论点
统计力学	比值	阐明	可行

Reading Material

Chemical Kinetics

Without chemical reaction our world would be a barren planet. No life of any sort would exist. Even if the fundamental reactions involved in life processes did exist without other chemical reactions taking place around us, our lives would be extremely different from what they are today. There would be no fire for warmth and cooking, no iron and steel with which to fashion even the crudest implements, no synthetic fibers for clothing, and no engines to power our vehicles.

One feature that distinguishes the chemical engineer from other types of engineers is the ability to analyze systems in which chemical reactions are occurring and to apply the results of his analysis in a manner that benefits society. Consequently, chemical engineers must be well acquainted with the fundamentals of chemical kinetics and the manner in which they are applied in chemical reactor design.

Chemical Kinetics deals with quantitative studies of the rates at which chemical processes occur, the factors on which these rates depend, and the molecular acts involved in reaction processes. A description of a reaction in terms of its constituent molecular acts is known as the mechanism of the reaction. Physical and organic chemists are primarily interested in chemical kinetics for the light that it sheds on molecular properties. From interpretations of macroscopic kinetic data in terms of molecular mechanisms, they can gain insight into the nature of reacting systems, the processes by which chemical bonds are made and broken, and the structure of the resultant product. Although chemical engineers find the concept of a reaction mechanism useful in the correlation, interpolation, and extrapolation of rate data, they are more concerned with application of chemical kinetics in the development of manufacturing processes.

Chemical engineers have traditionally approached kinetics studies with the goal of describing the behavior of reacting systems in terms of macroscopically observable quantities such as temperature, pressure, composition, and Reynolds number. This empirical approach has been very fruitful in that it has permitted chemical reactor technology to develop to a point that far surpasses the development of theoretical work in chemical kinetics.

The dynamic view point of chemical kinetics may be contrasted with the essentially static viewpoint of thermodynamics. A kinetic system is a system in unidirectional movement toward a condition of thermodynamic equilibrium. The chemical composition of the system changes continuously with time. A system that is in thermodynamic equilibrium, on the other hand, undergoes no net change with time. The thermodynamicist is interested only in the initial and final states of the system and is not concerned with the time required for the transition of the molecular processes involved therein; the chemical kineticist is concerned primarily with these issues.

In principle one can treat the thermodynamics of chemical reactions on a kinetic basis by recognizing that the equilibrium condition corresponds to the cases where the rates of the forward and reverse reactions are identical. In this sense kinetics is the more fundamental science. Nonetheless, thermodynamics provided much vital information to the kineticist and to the reactor designer. In particular, the first step in determining the economic feasibility of producing a given material from a given reactant feed stock should be the determination of the product yield at equilibrium at the conditions of the reactor outlet. Since this composition represents the goal toward which the kinetic process is moving, it places a maximum limit on the product yield that may be obtained. Chemical engineers must also use thermodynamics to determine heat transfer requirements for proposed reactor configurations.

Selected form "Specialized Chemical English (unformal published) (the first volumn), by Cui Bo etc., 1994, 67-70"

New Words

1. kinetics [kai'netiks] *n.* 动力学
2. barren ['bærən] *a.* 不毛的，贫瘠的
3. cook ['kuk] *vt.* 烹调
4. implement ['implimənt] *n.* 工具，器具
5. vehicle ['vi:ikl] *n.* 车辆
6. distinguish [dis'tiŋgwiʃ] *vt.* 区别
7. benefit ['benifit] *vt.* 有益于
   vi. 受益
   n. 利益，好处
8. acquaint [ə'kweint] *vt.* 使认识，使熟悉
   acquaint oneself with (或 of) 使自己知道(熟悉)
9. shed [ʃed] *vt.* 放射，散发，流出，流下
   shed light on 阐明，把……弄明白
10. correlation [kɔri'leiʃən] *n.* 相互关系，伴随关系，关联（作用）
11. interpolation [intə:pəu'leiʃən] *n.* 内插法，插入，解释
12. extrapolation [ekstræpə'leiʃən] *n.* 外推法，推断，推知
13. behavior [bi'heiviə] *n.* 性能，性质，行为
14. Reynolds number 雷诺数
15. empirical [em'pirikəl] *a.* 经验（上）的
16. dynamic [dai'næmik] *a.* 动力（学）的
17. unidirectional ['ju:nidi'rekʃənl] *a.* 单向性的
18. issue ['isju:] *n.* 问题，论点，流出物，流出
19. identical [ai'dentikəl] *a.* 相同的，完全相同的
20. nonetheless [nʌnðə'les] *ad.* 仍然，不过（=nevertheless）
21. vital ['vaitl] *a.* 必需的，生命的
22. kineticist [kai'netisist] *n.* 动力学家
23. feasibility [fi:zə'biliti] *n.* 可行，可实行

Lesson 3

The Second Law of Thermodynamics

Thermodynamics is concerned with transformations of energy, and the laws of thermodynamics describe the bounds within which these transformations are observed to occur. The first law, stating that energy must be conserved in all ordinary processes, has been the underlying principle of the preceding chapters. The first law imposes no restriction on the direction of energy transformations. Yet, all our experience indicates the existence of such a restriction. To complete the foundation for the science of thermodynamics, it is necessary to formulate this second limitation. Its concise statement constitutes the second law.

The differences between the two forms of energy, heat and work, provide some insight into the second law. These differences are not implied by the first law. In an energy balance both work and heat are included as simple additive terms, implying that one unit of heat, such as a joule or BTU, is equivalent to the same unit of work. Although this is true with respect to a energy balance. Experience teaches that there is a difference in quality between heat and work. This experience can be summarized by the following facts.

First, the efficiency of the transformation from one form of work to another such as electrical to mechanical as accomplished in an electric motor, can be made to approach 100 percent as closely as is desired. One needs merely to exert more and more care in eliminating irreversibilities in the apparatus. On the other hand, efforts to convert energy transferred to a system as heat into any of the forms of work show this regardless of improvements in the machines employed. The conversion is limited to low values (40 percent is an approximate maximum). These efficiencies are so low, in comparison with these obtained for the transformation of work from one form to another, that there can be no escape from the conclusion that there is an intrinsic difference between heat and work, in the reverse direction, the conversion of work into heat with 100 percent efficiency is very common. Indeed, efforts are made in nearly every machine to eliminate this conversion, which decrease efficiency of operation. These facts lead to the conclusion that heat is a less versatile or more degraded form of energy than work. Work might be termed energy of a higher quality than heat.

To draw further upon our experience, we know that heat always flows from a higher temperature level to a lower one, and never in the reverse direction. This suggests that heat itself may be assigned a characteristic quality as well as quantity, and that this quality depends upon temperature, the relation of temperature to the quality of heat is evident from the increased in efficiency with which heat may be converted into work as the temperature of the source is raised. For example, the efficiency, or work output per unit of fuel burned, of a stationary power plant increases as the temperature of the steam in the boiler and superheater rises.

Statements of the Second Law

The observations just described are results of the restriction imposed by the second law on the direction of actual processes. Many general statements may be made which described this restriction and hence, serve as statements of the second law. Two of the most common are:

1. No apparatus can operate in such a way that its only effect (in system and surroundings) is to convert heat absorbed by a system completely into work.