化学工程专业英语

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English in Chemical Engineering

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内 容 提 要

本书介绍了化学工程中常用的几类单元操作中的一些基本概念、原理和工艺流程，包括精馏、蒸发、结晶、干燥和吸附等相关内容，并介绍了目前应用越来越广泛的膜分离新技术的主要特点和原理，最后简单介绍了化工产品开发、设计的工艺特点。

本书可作为化学工程专业的本科生教材，也可供从事化学工程科学研究的科研工作者和技术人员参考。

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前　言

化学工程是研究化学工业及其相关产业生产过程中所进行的化学过程、物理过程及其所用设备的设计与操作和优化的共同规律的一门工程学科。它以化学工程学科为指导，基础理论与工程应用相结合，涉及产品研制、工艺开发、过程设计、系统模拟、装备强化、操作控制、环境保护、生产管理等内容。化学工程领域涵盖了无机与有机化工、石油化工与煤化工、精细化工、生物化工、材料化工、冶金化工、环境化工等行业。它既是国民经济建设与社会发展的重要工程领域，又与信息、生物、材料、计算机、能源、海洋、航天等高新技术领域相互渗透，推动高新技术的发展。

目前国外化学工程领域正向集约化、连续化、高效化、自动化、精细化的方向发展，而国内有关的科技英文书籍却寥寥无几。了解和掌握本学科专业英语，是学生获取科学信息、掌握科学发展动态、参加学术交流的基本前提。为了提高高校学生、专业科技人员熟练运用英语来获得本学科的相关知识，提高科技交流的能力，我们编写了本书，期望能够有利于相关人员加深对化学工程领域基本概念的理解和应用，促进本学科更好的发展。本书在帮助学生了解理论知识的基础上，更希望能够传授给学生感性的、直接的、能真正在生产实践中应用的知识和经验。

全书内容主要可分为两个部分。第一部分在论述化学工程中的基本概念和原理的基础上，重点介绍了单元操作中的精馏、蒸发、结晶、干燥、吸附和膜分离的内容，叙述了有关化学反应、反应动力学和传质、传热等方面的知识。第二部分则从化工产品开发、设计的角度介绍了相应的工艺特点。本书在编写过程中充分考虑了专业英语阅读的特点，注重了专业术语的准确性，适合化工类学科的专业培养。

本书的第 0 章和第 1 章由大连海事大学刘炼编写，第 2、3 章

由哈尔滨工程大学郑卫编写，第4、5、7章由大连海事大学王沛编写，第6章由哈尔滨工程大学徐晓雪编写。

由于编写人员水平有限，成书时间仓促，书中疏漏之处在所难免，恳请读者批评指正。

编　者
2008年2月

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Introduction to Chemical Engineering

The understanding of the design and construction of chemical plant is frequently regarded as the essence of chemical engineering. Starting from the original conception of the process by the chemist, it is necessary to appreciate the chemical, physical and many of the engineering features in order to develop the laboratory process to an industrial scale. This book is concerned mainly with the physical nature of the processes that take place in industrial units, and, in particular, with determining the factors that influence the rate of transfer of material.

Throughout what are conveniently regarded as the process industries, there are many physical operations that are common to a number of the individual industries, and may be regarded as unit operations. Some of these operations involve particulate solids and many of them are aimed at achieving a separation of the components of a mixture. Thus, the separation of solids from a suspension by filtration, the separation of liquids by distillation, and the removal of water by evaporation and drying are typical of such operations. The problem of designing a distillation unit for the fermentation industry, the petroleum industry or the organic chemical industry is, in principle, the same, and it is mainly in the details of construction that the differences will occur. The concentration of solutions by evaporation is again a typical operation that is basically similar in the handling of sugar, or salt, or fruit juices, though there will be differences in the most suitable arrangement.

One of the difficult problems of design is that of maintaining conditions of similarity between laboratory units and the larger-scale industrial plants. Thus, if a mixture is to be maintained at a certain temperature during the course of an exothermic reaction, then on the laboratory scale there is rarely any real difficulty in maintaining isothermal conditions. On the other hand, in a large reactor the ratio of the external surface to the volume—which is inversely proportional to the linear dimension of the unit—is in most cases of a different order, and the problem of removing the heat of reaction becomes a major item in design. Some of the general problems associated with scaling-up are considered as they arise in the chapters. Again, the introduction and removal of the reactants may present difficult problems on the large scale, especially if they contain corrosive liquids or abrasive solids. The general tendency with many industrial units is to provide a continuous process, frequently involving a series of stages. Thus, exothermic reactions may be carried out in a series of reactors with interstage cooling.

The planning of a process plant will involve determining the most economic method, and later the most economic arrangement of the individual operations used in the process. This amounts to designing a process so as to provide the best combination of capital and operating costs. In this book the question of costs has not been considered in any detail, but the aim has been to indicate the conditions under which various types of units will operate in the most economical manner. Without a thorough knowledge of the physical principles involved in the various operations, it is not possible to select the most suitable one for a given process. This aspect of the design can be considered by taking one or two simple illustrations of separation processes. The particles in a solid-solid system may be separated, first according to size, and secondly according to the material. Generally, sieving is the most satisfactory method of classifying relatively coarse materials according to size, but the method is impracticable for very fine particles and a form of settling process is generally used. In the first of these processes, the size of the particle is used directly as the basis for the separation, and the second depends on the variation with size of the behaviour of particles in a fluid.

The problem of selecting the most appropriate operation will be further complicated by such factors as the concentration of liquid solution at which crystals start to form. Thus, in the separation of a mixture of ortho-, meta-, and para-mononitrotoluenes, the decision must be made as to whether it is better to carry out the separation by distillation followed by crystallization, or in the reverse order. The same kind of consideration will arise when concentrating a solution of a solid; then it must be decided whether to stop the evaporation process when a certain concentration of solid has been reached and then to proceed with filtration followed by drying, or whether to continue to concentration by evaporation to such an extent that the filtration stage can be omitted before moving on to drying.

In many operations, for instance in a distillation column, it is necessary to understand the fluid dynamics of the unit, as well as the heat and mass transfer relationships. These factors are frequently interdependent in a complex manner, and it is essential to consider the individual contributions of each of the mechanisms. Again, in a chemical reaction the final rate of the process may be governed either by a heat transfer process or by the chemical kinetics, and it is essential to decide which is the controlling factor.

Two factors of overriding importance have not so far been mentioned.

Firstly, the plant must be operated in such a way that it does not present an unacceptable hazard to the workforce or to the surrounding population. Safety considerations must be in the forefront in the selection of the most appropriate process route and design, and must also be reflected in all the aspects of plant operation and maintenance. An inherently safe plant is to be preferred to one with inherent hazards, but designed to minimize the risk of the hazard being released. Safety considerations must be taken into account at an early stage of design; they are not an add-on at the end. Similarly control systems, the integrity of which play a major part in safe operation of plant, must be designed into the plant, not built on after the design is complete. The second consideration relates to the environment. The engineer has the responsibility for conserving natural resources, including raw materials and energy sources, and at the same time ensuring that effluents (solids, liquids and gases) do not give rise to unacceptable environmental effects. As with safety, effluent control must feature as a major factor in the design of every plant.

The topics discussed in this book form an important part of any chemical engineering project. They must not, however, be considered in isolation because, for example, a difficult separation problem may often be better solved by adjustment of conditions in the preceding reactor, rather than by the use of highly sophisticated separation techniques.

Key words:

fermentation [发酵]

interstage [多级]

overriding [最重要的,高于一切的]

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Distillation

1.1 Introduction

The separation of liquid mixtures into their various components is one of the major operations in the process industries, and distillation, the most widely used method of achieving this end, is the key operation in any oil refinery. In processing, the demand for purer products, coupled with the need for greater efficiency, has promoted continued research into the techniques of distillation. In engineering terms, distillation columns have to be designed with a larger range in capacity than any other types of processing equipment, with single columns 0.4 ~ 12 m in diameter and 2 ~ 80 m in height. Designers are required to achieve the desired product quality at minimum cost and also to provide constant purity of product even though there may be variations in feed composition. A distillation unit should be considered together with its associated control system, and it is often operated in association with several other separate units.

The vertical cylindrical column provides, in a compact form and with the minimum of ground requirements, a large number of separate stages of vaporization and condensation. *In this chapter the basic problems of design are considered and it may be seen that not only the physical and chemical properties, but also the fluid dynamics inside the unit, determine the number of stages required and the overall layout of the unit.*[1] The separation of benzene from a mixture with toluene, for example, requires only a simple single unit as shown in Figure 1.1, and virtually pure products may be obtained. A more complex arrangement is shown in Figure 1.2 where the columns for thepurification of crude

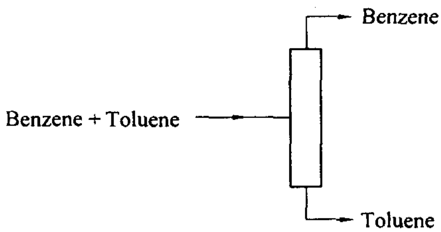


Figure 1.1 Separation of a binary mixture

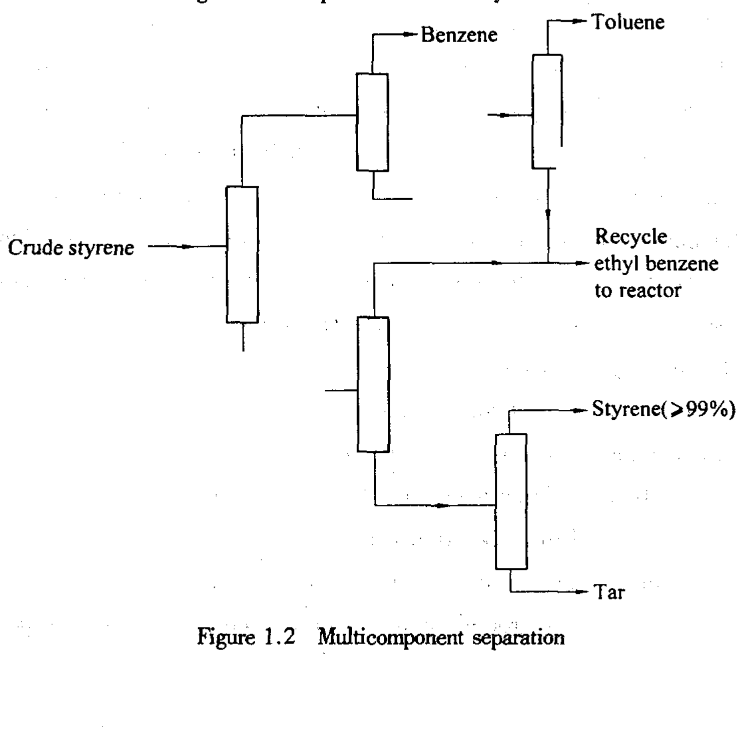


Figure 1.2 Multicomponent separation

styrene formed by the dehydrogenation of ethyl benzene are shown. It may be seen that, in this case, several columns are required and that it is necessary to recycle some of the streams to the reactor.

In this chapter consideration is given to the theory of the process, methods of distillation and calculation of the number of stages required for both binary and multicomponent systems, and discussion on design methods is included for plate and packed columns incorporating a variety of column internals.[2]

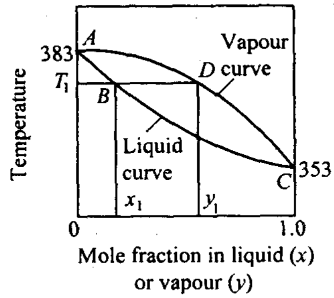
Notes:

[1] 在本章内容中,将涉及蒸馏操作设计中存在的一些基本问题,同时我们也会明白决定蒸馏中所需的塔板数和整体布局的因素不仅仅是被蒸馏液体的物理和化学性质而且还要考虑流体动力学的影响。

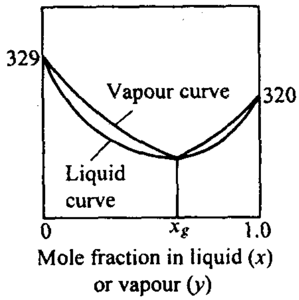
[2] 本章的内容涉及了蒸馏过程的一些理论、蒸馏的方法,还有二元和多元体系时塔板数的计算,同时还讨论了板式塔和填料塔的设计方法以及蒸馏塔的塔内构件的情况。

1.2 Vapour-liquid Equilibrium

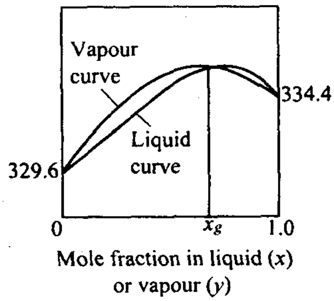
The composition of the vapour in equilibrium with a liquid of given composition is determined experimentally using an equilibrium still. The results are conveniently shown on a temperature—composition diagram as shown in Figure 1.3. In the normal case shown in Figure 1.3(a), the curve *ABC* shows the composition of the liquid which boils at any given temperature, and the curve *ADC* the corresponding composition of the vapour at that temperature. Thus, a liquid of composition x_1 will boil at temperature T_1, and the vapour in equilibrium is indicated by point D of composition y_1. It is seen that for any liquid composition x the vapour formed will be richer in the more volatile component, where x is the mole fraction of the more volatile component in the liquid, and y in the vapour. Examples of mixtures giving this type of curve are



(a) Benzene-toluene



(b) Acetone-carbon disulphide



(c) Acetone-chloroform

Figure 1.3 Temperature composition diagrams

benzene-toluene, *n*-heptane-toluene, and carbon disulphide-carbon tetrachloride.

In Figures 1.3(b) and (c), there is a critical composition x_g where the vapour has the same composition as the liquid, so that no change occurs on boiling. Such critical mixtures are called azeotrope. For compositions other than x_g, the vapour formed has a different composition from that of the liquid. It is important to note that these diagrams are for constant pressure conditions, and that the composition of the vapour in equilibrium with a given liquid will change with pressure.

1.2.1 Partial vaporization and partial condensation

If a mixture of benzene and toluene is heated in a vessel, closed in such a way that the pressure remains atmospheric and no material can escape and the mole fraction of the more volatile component in the liquid, that is benzene, is plotted as abscissa, and the temperature at which the mixture boils as ordinate, then the boiling curve is obtained as shown by *ABCJ* in Figure 1.4. The corresponding dew point curve *ADEJ* shows the temperature at which a vapour of composition y starts to condense.

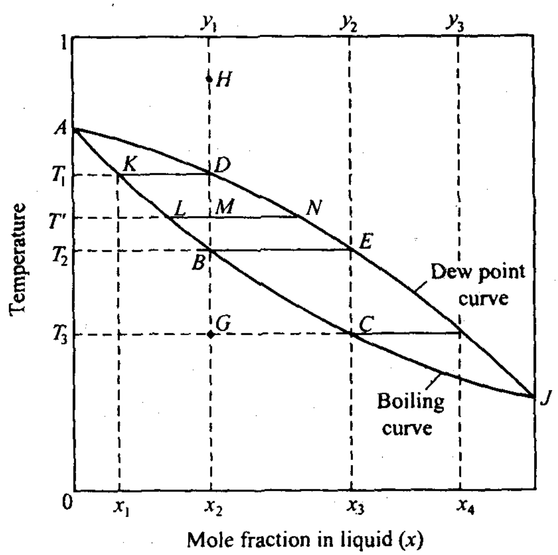


Figure 1.4 Effect of partial vaporization and condensation at the boiling point

If a mixture of composition x_2 is at a temperature T_3 below its boiling point, T_2, as shown by point G on the diagram, then on heating at constant pressure the following changes will occur:

(a) When the temperature reaches T_2, the liquid will boil, as shown by point B, and some vapour of composition y_2, shown by point E, is formed.