**Reading material A**

**Distillation**

Distillation may be carried out by either of two principal methods. The first method is based on the production of a vapor by boiling the liquid mixture to be separated and condensing the vapors without allowing any liquid to return to the still. The second method is based on the return of part of the condensate to the still under such conditions that this returning liquid is brought into intimate contact with the vapors on their way to the condenser. Either of these methods may be conducted as a continuous process or as a batch process.

**Flash distillation**

Flash distillation consists of vaporizing a definite fraction of the liquid in such a way that the evolved vapor is in equilibrium with the residual liquid, separating the vapor from the liquid, and condensing the vapor. Feed is pumped by pump through heater, and the pressure is reduced through valve. An intimate mixture of vapor and liquid portions to separate. Because of the intimacy of contact of liquid and vapor before separation, the separated streams are in equilibrium. Vapor leaves through a line on the top and liquid through the line attached to the bottom.

A special distillation problem is encountered when the boiling point of the material is so high that the substance decomposes at its atmospheric boiling point; or the vaporization temperature cannot easily be reached by stream heat. To distill such a material, either to free it from nonvolatile impurities or to separate it into fractions of differing boiling point, the distillation temperature must be lowered to a point where the liquid can be vaporized without reaching excessive temperatures. One method of accomplishing this is to operate under a vacuum. This method, using high-temperature heating and efficient vacuum—producing equipment, is extensively used in both batch and continuous processes. An important older method which utilizes simpler equipment is steam distillation. In this method, the temperature of the liquid is reduced by vaporizing the material into a stream of carrier vapor, the liquid phase is immiscible with the material distilled. A mixture vapor of carrier and vaporized material is taken overhead and condensed, and the liquid layers, each containing one of the component, are separated by gravity. Although any inert carrier can be used, for economy steam is the usual choice. Steam distillation can be combined with rectification, usually in continuous fractionating columns, often under a partial vacuum. Lubricating oils are treated in this manner.

**Rectification**

Flash distillation is used most for separating components which boil at widely different temperatures. It is not effective in separating components of comparable volatility, since then both the condensed vapor and residual liquid are far from pure. By many successive redistillations small amount of some nearly pure components may finally be obtained, but this method is too inefficient for industrial distillations when nearly pure components are wanted. Modern methods used in both laboratory and plant apply the principle of rectification.

Consider a single plate in a column or cascade of ideal plates. Assume the plates are numbered serially from top down and that the plate under consideration in the *n*th plate from the top. One liquid stream and one vapor stream enter the plate, and one liquid stream and one vapor stream leave it. Although the streams entering it are not in equilibrium, those leaving are in equilibrium. Some of the more volatile component is vaporized from the liquid, decreasing its concentration in the liquid, and some of the less volatile component if condensed from the vapor, increasing its concentration in the liquid. Since the liquid streams are at their bubble points and the vapor streams at their dew points, the heat necessary to vaporize the more volatile component must be supplied by the heat released in the condensation of the less volatile component. Two pure components can be obtained from the two output streams.

The plant, in which the feed to the units is supplied to the still, cannot produce a nearly pure bottom product because the liquid in the still is not subjected to rectification. This limitation is removed by admitting the feed to a plate in the central portion of column. Then the liquid feed flows down the column to the still, which in this type of plant is called the reboiler, and is subjected to rectification by the vapor rising from the reboiler. Since the liquid reaching the reboiler is stripped of the more volatile component, the bottom product can be nearly pure less volatile component.

**Design and operation of plate columns**

Important factors in the design and operation of plate columns are the number of the plates required to obtain the desired separation, the diameter of the column, the heat input to the reboiler and the heat output from the condenser, the spacing between the plates, the choice of type of plate, and the details of construction of the plates. In accordance with general principles, the analysis of the performance of plate columns is based on material balances, energy balances, and phase equilibria.

In the analysis of columns there are a lot of important factors which are widely used in practice: reflux ratio, condenser and top plate, bottom plate and reboiler, feed plate, construction of operation lines, minimum numbers of plates, minimum reflux, invariant zone, and optimum reflux ratio.

To translate ideal plates into actual plates, a correction for the efficiency of the plates must be applied. There are two other different decisions, some at least as important as fixing the number of plates, that must be made before a design is complete. A mistake in these decision results in poor fractionation, lower-than-desired capacity, poor operating flexibility, and, with extreme errors, an inoperative column. Correcting such errors after a plant has been built can be costly. Since many variables that influence plate efficiency depend on the design of individual plates, the fundamentals of plate design are discussed first.

The extent and variety of rectifying columns and their applications are enormous. The largest units are usually in the petroleum industry, but large and very complicated distillation plants are encountered in fractionating solvents, in treating liquefied air, and in general chemical processing. Tower diameters may range from 0.3m to more than 9m and the number of plates from a few plates to scores. Plate spacings may vary from 0.2m or less to about 1m. formerly bubble-cap plates were most common; today most columns contain sieve trays or lift-valve plates. Many types of liquid distribution are specified. Columns may operate at high pressures or low. The materials distilled can vary greatly in viscosity, diffusivity, corrosive nature, tendency to foam, and complexity of composition. Plate towers are as useful in absorption as in rectification, and the fundamental of plate design apply to both operations.

Designing fractionating columns, especially large units and those for unusual applications, is best done by experts. Although the number of ideal plates and the heat requirements can be computed quite accurately without much previous experiences, other design factors are not precisely calculable, and a number of equally sound designs can be found for the same problem. In common with most engineering activities, sound design of fractionating columns relies on a few principles, on a number of empirical correlations, and much experience and judgment.

1. **Complete the summary of reading material A. choose no more than three words from the passage for each answer.**

There are two principal methods to carry out distillation. One is 1 flash distillation and the other is 2 rectification .

During flash distillation when the boiling point of one material is higher than its 3 decomposing temperature or the vaporization temperature cannot be easily reached by steam heat, the 4 distillation temperature must be lowered to a point where the liquid can be vaporized without reaching excessive temperature. There are two methods to accomplish this, one is to operate distillation 5 under a vacuum , and the other is to use 6 Steam distillation/ inert carrier .

When nearly pure components are wanted, modern methods used in both laboratory and plant apply the 7 principle of rectification . During rectification, the feed is added to a plate in the central portion of column, then the 8 more volatile component is concentrated in the vapor, and 9 less volatile component is concentrated in the liquid, finally, two pure components can be obtained from the two output streams. The top product is nearly pure more volatile component, while the 10 bottom product . is nearly pure less volatile component.

Important factors in the design and operation of plate columns are the 11 number of plates , the column diameter, the heat input to the reboiler and the heat output from the condenser, 12 the plate spacing , the choice of plate type, and the 13 plate construction details . 14 Plate efficiency , which depend much on the design of individual plate, have to be taken into account when design a plate column and translate ideal plates into actual plates. In common, the designing of distillation column is suggested to be done by 15 experts .

**Reading material B**

**Sulphonation process for active detergents**

This is a brief description of the sulphonation processes used for manufacture of active detergents. To raise SO3/air with a volumetric content between 4 and 7%SO3, the process air be dried to prevent the formation of sulphuric acid mist.

Filtered ambient is compressed (about +5oC) to remove the major part of water by condensation and subsequently dried with a desiccant (silica gel, Alumina) to arrive a process air dew point of about -60oC.

Molten Sulphur (150oC) from storage is pumped to the Sulphur furnace where sulphur is converted with an excess of oxygen from the process air to SO2 (4-7% SO2 by volume in “air”). The furnace of the SO2/air varies with exothermic character of the reaction. The SO2/air flow is cooled in an indirect air cooler from 600-700oC to about 420oC.

SO2 is converted to SO3 in the so-called converter tower filled with 4 packed beds of V2O5 catalyst on a silica carrier. The reaction is highly exothermic and intermediate cooling of the process gas flow between the various beds with indirect air cooler is required.

Notwithstanding the low process air dew point, some sulphuric acid/oleum mist condenses in the cooler following the converter tower at temperatures of about 45-50oC. This highly reactive mist can affect the quality of the subsequent sulphonation reaction and therefore a high-efficiency demister is installed before the actual sulphonation step. The sulphonation reaction between SO3 and organic feedstock is almost instantaneous and the reaction is highly exothermic.

Falling film reactor of different design are nowadays widely used for the sulphonation reaction.

After the reactor, the SO3 exhausted gas is separated from the organic acid. The exhaust gas, containing small amounts of non-converted SO2, unreacted SO3 and some entrained organic acid, has to be cleaned before emission to ambient atmosphere. The organic aerosol and fine SO3/H2SO4 droplets are separated from the exhaust gas flow in an electrostatic precipitator (ESP) and the gaseous SO2 and traces of SO3 gas are washed from the process air in a scrubber by dilute caustic solution, thus producing a mixed sulphite/sulphate solution.

The neutralization reactions can be carried out with many alkaline chemicals like caustic, ammonia and sodium carbonate. The reaction with diluted caustic to a paste containing between 40 and 70% AD, depending on organic acid type, is most widely used.

Various loop-type reactors, consisting of circulation pump, homogenizer (where the acid is introduced in the circulating alkaline paste) and heat exchanger, are used for the complex neutralization step.

The SO3/air gas-raising plant is an example of a “heavy” chemical industry operation. Highly corrosive and hazardous chemicals like SO2, SO3 and SO3/oleum sulphuric acid mist are produced at elevated temperatures.

The sulphonation and neutralization reactions themselves are delicate in the sense that inaccurate operations lead to undesired by-products, bad colors and poor yield of converted organic feedstocks.

Poorly controlled operation may cause hazardous situation to people on site and in the adjacent surroundings.

1. **Complete the scheme according to the reading material B.**

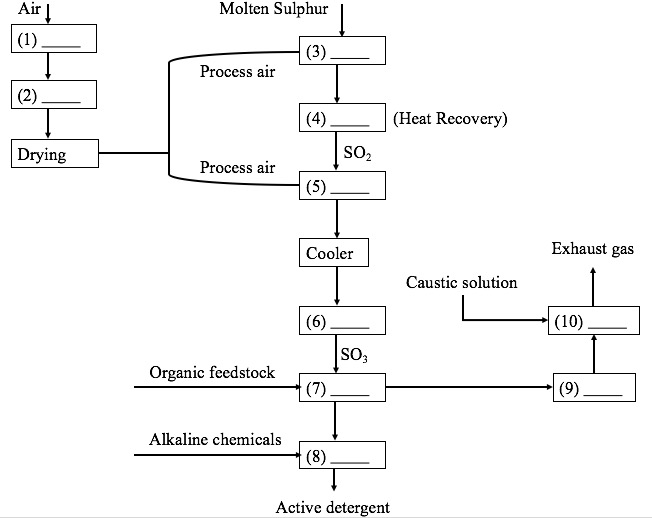
1 filtering 2 compressing

3 sulphur furnace 4 cooler

5 converter tower 6 high-efficiency demister

7 falling film reactor 8 loop-type reactor

9 electrostatic precipitator 10 scrubber



1. **Translate the following passages into Chinese.**

Passage 1

Batch reactors are generally used for liquid phase reaction. When a solid catalyst has to be kept in suspension or when there are two liquid phases, an agitator is required. Consequently, the batch reactor is generally considered to be spatially uniform in composition and temperature.

Passage 2

Flash distillation is used most for separating components which boil at widely different temperatures. It is not effective in separating components of comparable volatility, since then both the condensed vapor and residual liquid are far from pure. By many successive redistillations small amount of some nearly pure components may finally be obtained.

Passage 3

The cracking of hydrocarbons on acid catalysts is a long established and critically important industrial process. Developed in the 1930s, “cat cracking” quickly replaced thermal cracking in the commercial production of motor fuels. Since then, cracking technology has undergone many major improvements.

Passage 4

Petroleum is a complex mixture of hydrocarbons that occurs in the earth in liquid, gaseous, or solid forms. The term is usually restricted to the liquid form, commonly called crude oil, but as a technical term it also includes natural gas and the viscous or solid form known as bitumen.

Passage 5

Plastics additives are typically organic molecules that are added to polymers in small amounts during manufacture or processing, so as to improve the inherent properties of the polymer resin. Additives can be categorized in three major segments: polymer modifiers, performance enhancers, and processing aids.