Unit 2

Chemical Engineering

Pre-Reading

What's the difference between chemistry and chemical engineering?

Reading

The definition of Chemical Engineering accepted by the American Institute of Chemical Engineers at present is as follows:

Chemical engineering is the application of the principles of the physical sciences together with the principles of economics and human relations to fields that pertain directly to processes and process equipment in which matter is treated to effect a change in state, energy content, or composition.

The basic objective of chemical engineers is to produce chemical products as a profit. To meet this objective, they must be interested not only in the design, construction, and operation of individual pieces of equipment, but also in the development of entire manufacturing processes. The general scheme of development of a new process involves numerous steps. A new product for which a demand seems apparent is developed by a chemist in most cases. In general, he works with small hench-sized apparatus. The engineering group of a company is given the job of evaluating the possibilities of building a plant to mass-produce this chemical.

After preliminary evaluation, including market research by the sales division, it may he desirable to carry out pilot-plant studies. These are done in a small plant. producing perhaps 100 lb. a day, where studies are made concerning the proper range of temperature, pressure, composition, time, etc. to make the product economically. Other factors such as safety hazards, materials of construction, and waste disposal are also considered here. This work is usually done by chemical engineers. If the pilot-plant seems favorable, full-scale design may he undertaken.

Calculations of quantities of materials, energy balances, plant layout, and approximate equipment size are usually done by chemical engineers. Detail design of equipment, controls, electrical wiring, etc. is then usually done by mechanical, civil, architectural, and other engineers and specialists.

During plant construction numerous members of the engineering department are on hand to check progress and to advise on questionable details. After the plant is built, the supervision of testing and putting the plant into smooth operation is done by chemical engineers. They also usually supervise normal operating and testing during production. Most chemical engineers are in the above work. Others are found in related fields such as teaching, pure research, and technical sales.

Substitution

What do the words in italics refer to?

1. That in sentence 1 refers to:

   a) those fields related to processes and process equipment.
   b) fields in which production state, energy content or composition can be changed.
   c) principles of economics and human relations.

2. They in sentence 3 refers to:

   a) chemical products
   b) objectives
   c) chemical engineers

3. Where in sentence 9 refers to:

   a) in market research
   b) in a small plant
   c) in pilot-plant studies

4. This in sentence 11 refers to:

   a) preliminary evaluation
   b) the study at pilot-plant scale
   c) waste disposal

5. They in sentence 17 refers to:

   a) members of the engineering department
   b) chemical engineers

c) operation supervisors

True or False

Decide whether the statements are true (T) or false (F).

1. Chemical engineers combine the science of chemistry with the discipline of engineering in order to solve problems and find more efficient ways of doing things.

2. The chemical engineer develops industrial processes whose products are worth little money and works with small amounts of material economically.

3. Often the commercial success or failure of a product depends on the efforts of the chemical engineer in designing a pilot plant and subsequent full-scale plant.

4. Chemical engineers work in many phases of the production of chemicals and chemical products.

5. The chemical engineers cannot apply principles of other fields such as physics, mathematics, mechanical and electrical engineering to the chemical engineering.

6. Chemical engineers are not responsible for the production of the food we eat and the purification of water and air as well as raw materials found in our oceans.

Comprehension Questions

Answer the questions below.

1.What are chemical engineers responsible for?
2. List basic steps in the industrial production of a chemical product. Give some examples to illustrate this.
3. Suggest some kinds of work that a chemical engineer can do in the fields such as teaching, pure research, technical sales. etc.
4. What chemical plant in VN do you know and what does it produce?

Making Definitions

The most common form of formal definitions contains five elements as follows:

(1)	(2)	(3)	(4)	(5)

Ex: chemical engineer / person / develop / design / new process of chemical production

Make definitions using terns and information given in the table below.

chemical science	branch / natural science / deal / composition / properties / reactions / substances

A chemical engineer	is	a person	who	develops or designs a new process of chemical production

chemical industry	manufacture / chemicals
chemical engineers	re-design / improve / troubleshoot / process / make / do / something / as / economically / safely 1 efficiently / as / possible
chemical plant	industrial plant / produce / chemicals
chemical process	process / determine / atomic / molecular / composition / structure / substances / involve
chemical reactor	apparatus / hold / substances / undergo / chemical reaction
chemical phenomenon	natural phenomenon / involve / chemistry
chemical mechanism	atomic process / occur / chemical reaction

Additional Reading

What Do Chemical Engineers Do?

It would take too long to list all the products that are impacted by chemical engineers, but knowing what industries employ them may help you comprehend the scope of their work.

Chemical engineers work in manufacturing, pharmaceuticals, healthcare, design and construction, pulp and paper, petrochemicals, food processing, specialty chemicals, microelectronics, electronic and advanced materials, polymers, business services, biotechnology, and environmental health and safety industries, among others.

Within these industries, chemical engineers rely on their knowledge of mathematics and science particularly chemistry to overcome technical problems safely and economically. And, of course, they draw upon and apply their engineering knowledge to solve any technical challenges they encounter. Don't make the mistake of thinking that chemical engineers only "make things'', though. Their expertise is also applied in the areas of law, education, publishing, finance, and medicine, as well as in many other fields that require technical training.

Specifically, chemical engineers improve food processing techniques, and methods of producing fertilizers, to increase the quantity and quality of availahle food.

They also construct the synthetic fibers that make our clothes more comfortable and water resistant; they develop methods to mass-produce drugs, making them more affordable; and they create safer, more efficient methods of refining petroleum products, making energy and chemical sources more productive and cost effective.

Chemical engineers also develop solutions to environmental problems, such as pollution control and remediation.

And yes, they process chemicals, which are used to make or improve just about everything you see around you.

Chemical engineers face many of the same challenges that other professionals face, and they meet these challenges by applying their technical knowledge, communication and teamwork skills; the most up-to-date practices available; and hard work. Benefits include financial reward, recognition within industry and society, and the gratification that comes from working with the processes of nature to meet the needs of society.

Unit Operations of Chemical Engineering

The steps in the production of every chemical may be divided into three major groups. With few exemptions, the focal point of every plant is the reactor, where a chemical change from reactants to products is caused to occur.

Before the reactants enter the reactor, they may pass through numerous pieces of equipment. The primary function of this equipment is to place the reactants at the proper temperature, pressure, composition, purity, and phases to meet the design requirements for the reactor.

When the products leave the reactor, they must be processed. Often a mixture of products, contaminants, and unused reactants must be treated to obtain the various products in sufficiently pure form for the market.

In general, all the equipment except the reactor is used to cause physical changes-blending, separating, heating, cooling, pumping, etc.

The various physical operations, such as fluid Clow, heat transmission, and distillation, are called unit operations. The reason for such classification is that the principles of any operation, such as distillation, are the same regardless of other differences which may exist between two plants. Chemical reactions may be classified as oxidation, nitration, hydrogenation, etc. and are divided into unit processes.

As mentioned above, unit operations are physical in nature. Their purpose is to process materials -reactants and products- to desired specifications of temperature, pressure, composition, and phase. From the standpoint of purpose, they fall into five major divisions:

Fluid flow

Heat transmission

Blending operations, such as agitation and mixing

Separation operations, such as distillation, extraction, absorption, adsorption, evaporation, crystallization, humidification, drying, filtration, and centrifugation. Solid handling, such as crushing, grinding, screening. and fluidization. There is no clear division between some of the operations. Continuous evaporator calculations, for example, require fluid flow equations to determine pipe and pump sizing and heat-transfer equations to size the steam coils and condenser. In some cases crystallization may occur in the evaporator. It is thus to your advantage to look upon an evaporator as a piece of equipment where the processes of fluid flow, heat transmission, and possibly crystallization are utilized to effect a change in the composition of a solution.

Theory of Distillation

In the simplest mixture of two mutually soluble liquids, the volatility of each is undisturbed by the presence of the other. In such a case, the boiling point of a 50-50 mixture, for example, would he halfway between the boiling points of the pure substances, and the degree of separation produced by a single distillation would depend only on the vapor pressure, or the volatility, of the separate components at this temperature. This simple relationship was first stated by the French chemist Francois Marie Raoult (i830-1901) and is called Raoult's law. Raoult's law applies only to mixtures of liquids that aie veiy similar in chemical structure, such as benzene and toluene. In most cases wide deviations occur from this law. Thus, one component is only slightly soluble in the other, its volatility is abnormally increased. In the example above, the volatility of alcohol in dilute aqueous solution is several times as great as predicted by Raoult's law. In extremely concentrated alcohol solutions, the deviation is even more striking: The distillation of 99 percent alcohol produces vapor that has less than 99 percent alcohol. For this reason, alcohol cannot he concentrated by distillation beyond 97 percent, even by an infinite number of distillations.

Distillation Apparatus

Technically, the term still is applied only to the vessel in which liquids are boiled during distillation, but the term is sometimes applied to the entire apparatus, including the fractionating column, the condenser, and the receiver in which the distillate is collected. The term still is also extended to cover apparatus for destructive distillation, or cracking. Stills for laboratory work are usually made of glass, but industrial stills are generally made of iron or steel. In cases in which iron would contaminate the product, copper is often employed, and small stills for the distillation of whiskey are frequently made of glass and copper. (The term retort is also sometimes used for a still.)

Fractional Distillation

If a portion of the distillate in the above example is returned from the condenser and made to drip down through a long column onto a series of plates, and if the vapor as it rises on its way to the condenser is made to bubble through this liquid at each plate, the vapor and liquid will interact so that some of the water in the. vapor condenses and some of the alcohol in the liquid vaporizes. The interaction at each plate is thus equivalent to a redistillation, and by building a column with a sufficient number of plates, 95 percent alcohol can be obtained in a single operation. Moreover, by feeding the original 10 percent alcohol solution gradually at a point in the middle of the column, virtually all the alcohol may he stripped from the water as it descends to the lowest plate, so that no alcohol need be wasted.

This process, known as rectification, fractionation, or tractional distillation, is common in industrial usage, not only for simple mixtures of two components (such as alcohol and water in fermentation products, or oxygen and nitrogen in liquid air) but also for highly complex mixtures such as those found in coal tar and petroleum. The fractionating column most often used is the so-called bubble tower, in which the plates are arranged horizontally a few centimeters apart and the ascending vapors are forced to rise through bubble caps in each plate and then bubble through the liquid. The plates are baffled so that the liquid flows from left to right on one plate, then overflows onto the plate below, and there flows from right to left. If the interaction between liquid and vapor is incomplete, or if frothing and entrainment occur so that some of the liquid is carried up by the vapor to the plate above, five actual plates might he required to do the work of four theoretical plates, producing four redistillations. An inexpensive equivalent of a bubble tower is the so-called packed column, in which the liquid flows down over a packing of earthenware rings or bits of glass tubing.

The only disadvantage of fractional distillation is that a large fraction (as much as one-half) of the condensed distillate must be refluxed, or returned to the top of the tower and eventually boiled again, and more heat must therefore he supplied. On the other hand, the continuous operation made possible by fractionation allows great heating economies, because the outgoing distillate may be used to preheat the incoming feed.

When the mixture consists of many components, they are drawn off at different points along the tower. Industrial distillation towers for petroleum often have over 100 plates, with as many as ten different fractions being drawn off at suitable points. Towers with more than 500 plates have been used for the separation of isotopes (see Isotope) by distillation.

Steam Distillation

If two insoluble liquids are heated, each is unaffected by the presence of the other (as long as they are agitated so that the lighter liquid does not form an impenetrable layer over the heavier), and vaporizes to an extent determined only by its own volatility. Such a mixture, therefore, always boils at a temperature lower than that of either constituent; and the percentage of each constituent in the vapor depends only on its vapor pressure at this temperature. This principle may be applied to substances that would be damaged by overheating if distilled in the usual fashion.

Vacuum Distillation

Another method of distilling substances at temperatures below their normal boiling points is to partially evacuate the still. Thus, aniline may be distilled at 100^0C by removing 93 percent of the air from the still. This method is as effective as steam distillation, but somewhat more expensive. The greater the degree of vacuum, the lower is the distillation temperature. If the distillation is carried on in a practically perfect vacuum, the process is called molecular distillation. This process is regularly used industrially for the purification of vitamins and certain other unstable products. The substance is placed on a plate in an evacuated space and heated. The condenser is a cold plate, placed as close to the first as possible. Most of the material passes across the space between the two plates, and therefore very little is lost.

Centrifugal Molecular Distillation

If a tall column of mixed gases is sealed and placed upright, a partial separation of the gases takes place as a result of gravity. In a high-speed centrifuge or an instrument called a vortex, the forces separating the lighter and heavier components from each other are thousands of times greater than gravity, making the separation more efficient. For example, separation of gaseous uranium hexa fluoride, UF_6, into molecules containing two different uranium isotopes, uranium-235 and uranium 238, may be effected by means of centrifugal molecular distillation.

Sublimation

If a solid substance is distilled, passing directly into the vapor phase and back into the solid state without a liquid being formed at any time, the process is called sublimation. Sublimation does not differ from distillation in any important respect, except that special care must be taken to prevent the solid from clogging the apparatus. Rectification of such materials is impossible. Iodine is purified by sublimation.

Destructive Distillation

If a substance is heated to a high temperature and decomposed into several valuable products, and these products are separated by fractionation in the same operation, the process is called destructive distillation. The important applications of this process are the destructive distillation of coal for coke, tar, gas, and ammonia. and the destructive distillation of wood for charcoal, acetic acid, acetone, and wood alcohol. The latter process has been largely displaced by synthetic processes for making the various by-products. The cracking of petroleum is similar to destructive distillation.