

Fundamentals & Applied Chemistry

Introduction:

Applied chemistry is the application of the principles and theories of chemistry to answer a specific question or solve a real world problem, as opposed to pure chemistry, which is aimed at enhancing knowledge within the field. Applied chemistry is increasingly important in solving environmental problems and contributing to the development of new materials, both of which are key issues in the 21st century. The products of the chemical industry can be divided into three categories:

(i) Basic chemicals: These are the chemicals produced in large volumes and purchased on the basis of chemical composition, purity and price. They are known as basic chemicals because they are the main chemicals used for the production of other chemical products. For example, ethanoic acid is sold on to make esters, which is then sold to make paints and finally sold to consumer.

(ii) Functional chemicals or special chemicals:

These are of a specific categories used in further manufacture and covers very high valued chemical and sold at very high margin or profit. For example, flavourings, perfumes, cosmetics, industrial gases, etc.

(iii) Fine chemicals or consumer chemicals:

These are specialized finished products that are transformed from raw materials by undergoing various chemical processes in the chemical plants. For example, detergents, drugs, paints, soap, etc. are fine chemicals or consumer chemicals.

Chemical industry and its importance:

Chemical industry is one of the most diverse manufacturing industry which is concerned with manufacture of synthetic products like cement, plastics, glass, paint, medicines, fertilizers, etc.

The importance of chemical industries are as follows:-

(i) Importance of chemicals industry in agriculture:

The agricultural industry makes use of different chemicals like fertilizers, insecticides, fungicides, pesticides, etc. which are used to protect crops.

(ii) Importance of chemical industries for painting and coating:

The paint manufacturing industry plays an important role within specific sectors of the economy because they provide protective and decorative finishes for many products in various market.

(iii) Importance of petro-chemistry:

Petro-chemistry involves transforming crude oil and natural gas into basic petrochemicals such as ethylene, propylene, butadiene and benzene. Thus, chemical industry is important for refining crude oil into petroleum products.

(iv) Importance of pharmaceuticals:

These include health science, which deals with human and animal health and let to know how the body functions and provide knowledge to improve health and cure diseases.

(v) Importance of chemical industries for construction purpose:

The residential construction market is a major consumer of chemicals. Home construction and synthetic materials such as pipes and siding are manufactured from plastics. Construction demands for appliances, carpeting, furniture, etc. that are produced from chemical industries.

Stages in producing a new product:

Product development process is an essential process for any chemical business which desires success and survival in the market. The product development process starts from idea generation and ends with product development and commercialization. The steps involved in the new product development process are as follows:-

- (i) Idea generation: The first step of product development is an idea generation. Idea of producing new product is due to the collective brainstorming ideas through internal and external sources. Major sources of new product ideas are customers, competitors, distributors, suppliers; brainstorming of scientists, engineers, marketing people, managers, and salesmen.
- (ii) Screening: The second step is an idea screening. This stage is concerned with selecting the best and most feasible idea among the ideas generated at the first step.
- (iii) Concept development and testing: At this step, the selected idea is moved into development process. For the selected idea, different product concepts are developed. Out of several product concepts the most suitable concept is selected.

and introduced to a focus group of customer to understand their reaction.

- (iv) Business analysis: During this step, the market strategies are developed to evaluate market size, product demand, growth potential, and profit estimation. Further, it includes proper promotion of product, selection of distribution channel, etc.
- (v) Product development: The concept further moves to production of finalized product. Here the research and development department plays a key role in development of physical product for commercial production.
- (vi) Market testing: Now the product is ready to be launched in the market with a brand name, packaging, and pricing. Before full scale launching, the product is exposed to a carefully chosen sample of the population called test market. If the product is found acceptable in the test market, the product is ready to be launched in the desired target market.
- (vii) Commercialization: During this phase the product is produced in bulk on a continuous basis and launched across the target

market with a proper marketing strategy and plan.

Economics of production:

Economic theory is ~~is~~ at large extent driven by money focusing on prices, markets and costs. The economics of the chemical industry should be understood in order to establish it in the nation. The profitability analysis of the used chemical process in the projected industry should be studied under following heads:

(i) Capital investment: Capital investment is a sum of money provided to a company to further its business objectives. Usually, capital investments fall under two broad categories.

(a) Fixed capital: Capital investment refers to money used by business to purchase fixed assets, which are not movable and used to establish the industry such as land, machinery, building, etc.

(b) Working capital: Those capital investment refers to money invested in a business with the concept that the money is used to purchase fixed assets for day-to-day operations are working capital. It includes cash, inventory, account receivable,

accounts payable, etc.

- (iii) Total product cost: The cost involved in total production of a product are called total product costs. Usually, total product cost falls under two broad categories.
 - (a) General expenses: The cost that is used on the general running of an organization, rather than money spent on producing chemical products or selling services are general expenses. Example of general expenses includes rent, transportation of products, administrative purpose, etc.
 - (b) Manufacturing cost: The cost used for producing a finished product in a chemical industry is called manufacturing cost. Example of manufacturing cost includes cost of raw materials, operating cost of technician, labor, supervisor, etc.
- (iv) Economic analysis: Economic analysis is all about analyzing the economic aspects of chemical industry. The aim is to determine whether it operates effectively and how profitable it is. Usually, economic analysis falls under two broad categories,

(a) Market analysis and selling price: A market analysis provides information about industries, customers, competitors and other market variables such as income taxes, competition of the product with others, price-volume relation, total and new earning from the product, etc.

(b) Profitability analysis: Profitability analysis is a branch of financial analysis that consists in putting measures of profit into perspective. Analysis of project costs, return on investment, and interest rate of return, preparation of cost and profit charts determine the financial status of the chemical industry.

Cash flow in the production cycle:

The product life cycle is the model that represents a sales pattern for a product over a period of time. There are following five stages to the product life cycle.

(i) Research and development: It is the first stage of the production life cycle. This is where a firm has a research team look into possible new ideas and products for a business. The cash flow at this stage is very low.

(ii) Production: This is the point when the product life cycle begins. This is when the actual product is launched and does not include testing or research and development. Manufacturers at this stage spend a lot of money in order to create awareness. The cash flow at this stage would not be ~~very~~ positive.

(iii) Growth: If the product succeeds, sales will grow. Prices could still be high, but with increased competition prices will drop. The producer still advertises at a high level to fight off competition. Product starts to move into profitability. The cash flow starts to become positive.

(iv) Maturity: During this stage prices and profit fall, due to high competitive pressure. Growth rates become stable and weak firms are forced to leave the industry.

(v) Decline phase: In this phase, product sales gradually decline, leading to the eventual termination of the product. Eventually the product will become less interesting for purchasers, and the decline of the product will commence.

Running a chemical plant:

A chemical plant is an industrial process plant that manufactures chemicals, usually on a large scale. Chemical plants use specialized equipment, units and technology in the manufacturing process.

To run a chemical plant more efficiently, following points should be consider:-

1. Raw material storage: Storage of raw materials are necessary to avoid the fluctuations of the production and to avoid the interruptions of the production.
2. Feed preparation: This stage is required to prepare the raw materials at the appropriate purity in the right form and free of contaminants.
3. Reaction: This stage is the most important stage of a chemical process. The design engineers must design the reactor such that the desired products produced at the desired amount.
4. Separation: In this stage, the desired products are separated from the byproduct and the unreacted reactant. At times, the unreacted reactants are recycled to the reaction or the feed preparation stage.

5. Purification: In this stage, the main products are purified using various kinds of techniques in order to meet the standards or market/customer needs.
6. Product storage and sales: The amount of products to be stocked before sales depends on the nature of the products and customer demands.

Designing a chemical plant:

In chemical engineering, the design of chemical plant consists of two parts (i) Process design (ii) Plant design. Process design is about the process, like a circuit diagram in electronics and plant design is about the hardware which actually does it, like the chip or circuit board which runs the electronics. Process and plant designs are the focal point of chemical engineering practice.

Designing a chemical plant consists of three aspects:-

- (i) Preparation of flow sheets
- (ii) Process steps
- (iii) Design steps

(ii) Preparation of flow sheet diagram:

Process design normally starts with a process scheme or flow sheet. The flow sheet is the key document or road map in process design. Generally, in chemical engineering, block diagrams are used. They are rectangular box diagrams and gives the complete graphic layout of the involved steps in the process. An arrow used in block diagram points the start of process and final product is underlined. The importance of flow diagram are as follows:-

- (a) It shows the streams concentrations, flow rates and compositions.
- (b) It shows the operating conditions.
- (c) It shows operating performance.

(ii) Process steps:

In chemical industry, following steps are considered.

(a) Reaction of reactants

(b) Separation of the products

(c) Purification of the products

(iii) Design steps:

In chemical industry, following design steps are considered.

(a) Information collection

(b) Preparation of flow diagram

- (c) Designation of equipment in flow diagram
- (d) Designation of reactor
- (e) Selection of control instrumentation for monitoring and analysis of process
- (f) Selection of materials handling equipment like pipes, pumps, etc
- (g) Designation of process auxiliaries
- (h) Development of plant layout
- (i) Estimation of cost for each items.

Choice of Continuous or Batch processing:

All industrial plants require an extensive set of operating procedures which define the steps required. For example, to start the plant up, to shut the plant down, to isolate pieces of equipment for maintenance or to deal with emergency situations. The chemical processes may be run in continuous or batch operation.

(i) Batch operation:

Batch ~~operation~~ processes are designed to run intermittently. In batch operation, production occurs in the sequential steps in discrete batches. A batch of feedstock is fed into a process or unit, then the chemical process takes place, then the product and any other outputs are removed. Batch

operation is commonly used in smaller scale plants. However, batch processes are more flexible as they allow the production of multiple products with different grade or purity in the same equipment. Also, they are easier to clean and maintain sterile operation.

(ii) Continuous ~~process~~ operation:

Continuous operations are designed to operate 24 hours a day, 7 days a week, throughout a long period of time. In continuous operation, all steps are ongoing continuously in time.

During usual continuous operation, the feeding and product removals are ongoing streams of moving material, which together with the process itself, all take place simultaneously and continuously. Chemical plants or units in continuous operations are usually in a steady state or approximate steady state. Continuous processes are usually more economical than batch process especially for large scale production as their capital costs are much lower.

Environmental impact of chemical industry:

The impact of chemicals on environment and human health is a cause of increasing concern. It has adverse effects on environment, some of which are as follows:-

- (i) Exposure to certain hazardous substances such as polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), heavy metals, etc can lead to direct toxicological effect on man or environment from short or long term exposure.
- (ii) Volatile organic compounds like NO_x promote the formation of smog and SO_x is responsible for the formation of acid rain.
- (iii) CFCs are non-flammable and non-toxic, but they react with other substances in the stratosphere to destroy the ozone layer and this in turn lead to a greater incidence of skin cancer.
- (iv) Radioactive substance including naturally occurring radioisotopes such as ²³⁸U and its decay products ²²⁶Ra and ²²²Rn affect the environment and human health because of their radiological and chemical toxicity.

(v) Chemical hazards also includes fire, explosions, leakages or release of toxic or hazardous materials that can cause people illness, injury or disability.