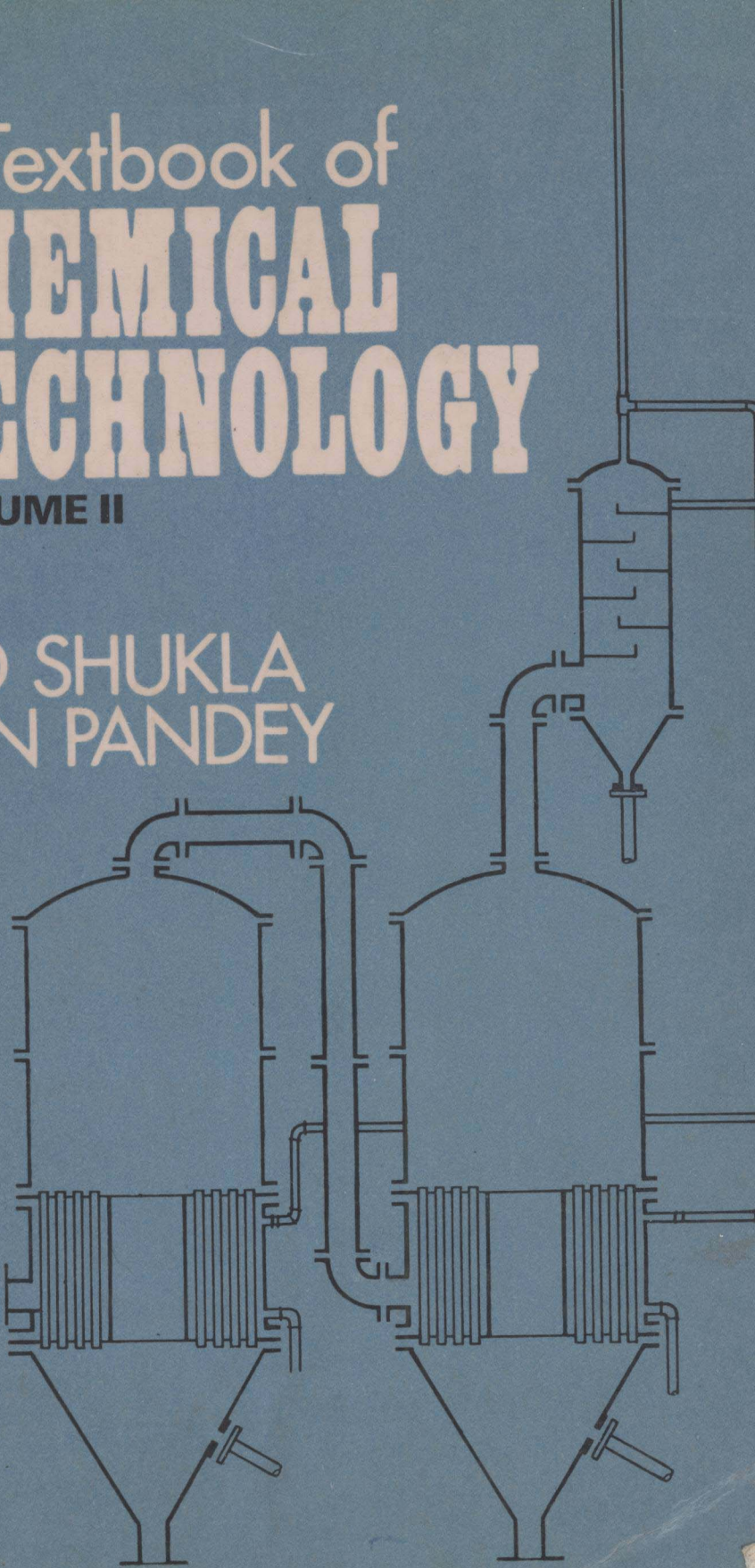
A Textbook of CHEMICAL TECHNOLOGY

VOLUME II

S D SHUKLA
G N PANDEY



A TEXTBOOK OF CHEMICAL TECHNOLOGY

VOL. II
(ORGANIC)

S. D. SHUKLA
Director,
Harcourt Butler Technological Institute
Kanpur

G. N. PANDEY
Professor and Head, Chemical Engineering Department
Harcourt Butler Technological Institute
Kanpur

VIKAS PUBLISHING HOUSE PVT LTD
New Delhi Bombay Bangalore Calcutta Kanpur

VIKAS PUBLISHING HOUSE PVT LTD
5 Ansari Road, New Delhi 110002
Savoy Chambers, 5 Wallace Street, Bombay 400001
10 First Main Road, Gandhi Nagar, Bangalore 560009
8/1-B Chowringhee Lane, Calcutta 700016
80 Canning Road, Kanpur 208004

1V02S8802

ISBN 0 7069 0755 8

Printed at Roopak Printers, Navin Shahdara, Delhi 110032

A TEXTBOOK OF CHEMICAL TECHNOLOGY, Vol. II
(ORGANIC)

PREFACE

This book is primarily intended as a textbook for undergraduate students of Chemical Engineering and Chemical Technology. The students reading in specialized training of different technology, *e.g.*, Petroleum Refining Engineering, Petro-chemicals, Oil Technology, Paint Technology, Plastic Technology, Food Technology and Biochemical Engineering will also find this book useful. Efforts have been made to cover the elective papers on these topics as prescribed by Chemical Engineering Education Development Centre, IIT, Madras. It is also expected to serve as reference book to the practicing Chemical Engineers, Industrial Chemists and Chemical Technologists. A fresh engineer is not only expected to know the basic principles of engineering but also to have sufficient knowledge of technology and operating conditions of a chemical plant. Because of the limited amount of time given to the course in technology for formal teaching in Engineering Institutions, we have considered it necessary to give in detail operating conditions to familiarise the students who have no background or previous experience of the technological processes. An attempt has been made to bridge the gap between the fundamental theory and engineering on one hand, and the practical use of knowledge in industry on the other. Selection of industries and processes was necessary to keep the volume of the book within limits.

The metric system prevalent in the country has been adopted as far as possible and informations have been given in terms of kilogram, metric ton, K Cal., atmosphere, cubic metres although the engineering data in the literature is generally available in British system.

An attempt has been made to bring out a comprehensive volume on organic technology devoted to Indian conditions. The Engineering Institutions in the country have been following books on Chemical Technology with little attention to the practice followed in India. India has made rapid strides in the growth of chemical industry during the last decade. Hence, there is justification for emphasizing the conditions prevalent in this country in the form of a book.

It is impossible for us to acknowledge individually contributions that have been made to the writing of this book. Assistance provided by S. K. Awasthi, Dhirendra, V. K. Jain, R. P. Kumar, G. N. Mathur, D. K. Pathak, J.P. Pathak, M. S. Saxena, G. Shanker, S. K. Shukla, S. N. Srivastava, A. K. Vashistha and S. N. Yadav is gratefully acknowledged.

It could not have been written without the help of the experts in the field because the industries covered are rather wide and it is beyond the personal knowledge of any individual. Published literature on the subjects and technical

journals have been freely consulted and information has been taken from them. Many of the statistical data have been obtained from the reports published by DGTD, and other journals. We are truly grateful to them.

The authors will greatly appreciate being informed of errors and receiving constructive criticism.

AUTHORS

CONTENTS

1.	Introduction	1
2.	Petroleum Refining and Petro-chemicals	25
3.	Mechanism of Polymerization	90
4.	Synthetic Fibres	101
5.	Natural and Synthetic Rubber	122
6.	Plastics	149
7.	Oils and Fats	179
8.	Essential Oils	223
9.	Paints, Varnishes and Lacquers	253
10.	Pulp and Paper Technology	268
11.	Sugar Technology	290
12.	Fermentation and Food Industries	299
13.	Leather and Allied Industry	365
14.	Dyes Industry	379
15.	Pesticides	389
16.	Coal and Coal Chemicals	431
17.	Drugs and Pharmaceutical Industry	468
	Appendix	477

CHAPTER 1

INTRODUCTION

Chemical Engineers deal with processes which are defined as change of state taking place in any system. There are three questions generally asked about any process:

1. How is it going to be carried out?
2. How far is it going to be carried out?
3. How fast is it going to be carried out?

First question *how* falls within the jurisdiction of unit processes or unit operations depending upon whether the change required is chemical or physical in nature. Chemical changes could be brought about only by unit processes while unit operations are a must for physical changes.

The second question *how far* concerns thermodynamics as the ultimate limit of conversion must be known in order to decide the extent to which a process may be carried out, for example, in the case of chemical reaction, it is essential to know the equilibrium conversion which subsequently helps in determining the optimum conversion.

Third question *how fast* deals with the rate of chemical reaction and falls in the jurisdiction of kinetics which eventually determines the time required for the completion of the process.

It is, therefore, obvious that some information on unit operations, unit processes, thermodynamics and chemical engineering kinetics will help the readers in going through the text. However, exhaustive treatment of these subjects will not be possible here.

UNIT OPERATIONS

Unit operations and now more recent Transport Phenomena may be broadly classified as:

(1) Momentum transport, (2) Heat transport, and (3) Mass transport.

Each one is again sub-classified into a set of unit operations. Unit operations often used in chemical industries are:

1. (*a*) Crushing;
(*b*) (*i*) Grinding, (*ii*) Screening;
(*c*) Fluid flow;
(*d*) (*i*) Filtrations, (*ii*) Centrifugation;
(*e*) (*i*) Sedimentation, (*ii*) Classification, (*iii*) Floatation, (*iv*) Fluidization.
2. (*a*) Conduction;
(*b*) Convection—(*i*) Natural, (*ii*) Forced.
(*c*) Condensation;

(*d*) Radiation;
(*e*) Evaporation;
(*f*) Crystallization.
3. (*a*) Solid-liquid extraction
(*b*) Liquid-liquid extraction
(*c*) (*i*) Vapour-liquid extraction, (*ii*) Distillation;
(*d*) Diffusion;
(*e*) Absorption;
(*f*) Adsorption;
(*g*) Drying;
(*h*) Humidification;
(*i*) Dehumidification;

A list of equipments with their applications is given in Table 1.1.

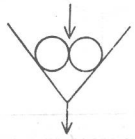
UNIT PROCESSES

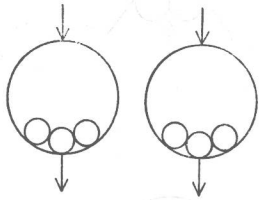
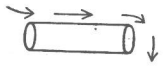
Following unit processes are very often used in chemical industries.

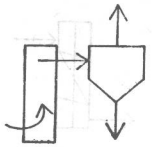
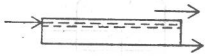
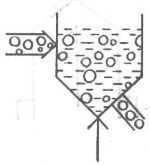
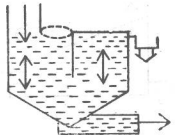
(*a*) Oxidation;
(*b*) Reduction;
(*c*) Hydrogenation;
(*d*) Dehydrogenation;
(*e*) Sulphonation;
(*f*) Sulphation;
(*g*) Halogenation—(*i*) Chlorination, (*ii*) Bromination (are most commonly used halogenations);
(*h*) Nitration;
(*i*) Isomerization;
(*j*) Polymerization;
(*k*) Amination;
(*l*) Esterification;
(*m*) Hydrolysis;
(*n*) Alkylation.

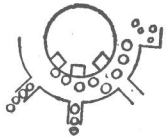
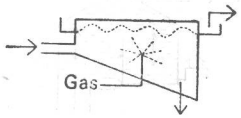
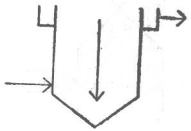
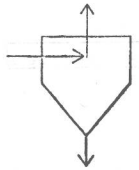
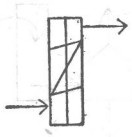
Some of the unit processes as with their brief descriptions and typical applications are given in Table 1.2.

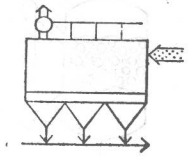
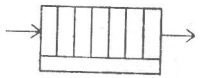
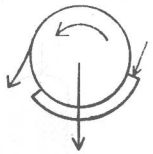
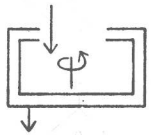
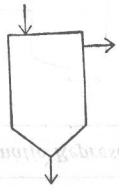
TABLE 1.1
EQUIPMENTS WITH THEIR APPLICATIONS

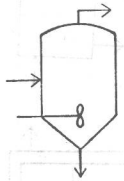
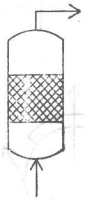
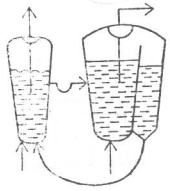
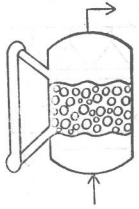
Unit Operation	*Schematic Representation*	*Application*	*Remarks*
1. SIZE REDUCTION			
(*a*) *Coarse*			
(*i*) Jaw crusher		For crushing hard materials like lime-stone, bricks etc.	Crushing is accomplished when the movable jaw moves towards the fixed jaw.
(*ii*) Dodge crusher		For crushing hard materials.	Produces more closely-sized product.
(*iii*) Roll crusher		For crushing soft materials like coal, gypsum, ice, etc.	Crushing is accomplished by pressure of teeth against the large lumps of the material.
(*iv*) Hammer mill		For crushing soft material like coal and fibrous material.	Crushing is accomplished by hammering the material against the breaks plate,
(*b*) *Intermediate*			
(*i*) Cone crusher		For crushing coarse size hard feed material.	Crushing is accomplished between two cones, the inner cone is rotating, while the outer cone is stationary.
(*ii*) Crushing rolls		For crushing coarse size hard feed material.	Crushing is done between two heavy cylinders revolving towards each other.

Unit Operation	*Schematic Representation*	*Application*	*Remarks*
(*c*) *Fine Size*			
(*i*) Ball mills		Used for the production of fine size material.	Size reduction is accomplished by the impact of balls.
(*ii*) Rod mills		Used for the production of fine size material.	Size reduction is accomplished by the impact of rods.
2. SOLID HANDLING			
(*i*) Screw conveyors		Used to handle powder and sticky material; also material like grains, crushed coal and sand etc.	Handling is affected by screw action. They can be operated under pressure.
(*ii*) Belt conveyors		Used to handle large volume over long distances economically, they are adopted to wide varieties and quantities of materials and require low power.	Belt may be of steel, canvass or rubber.
(*iii*) Bucket elevator		Used for lifting grains, ashes, powdered or granular materials.	Used when the direction of travel is vertical.

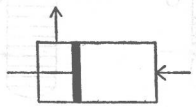
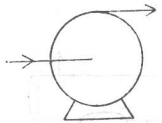
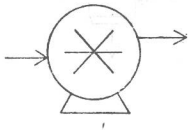
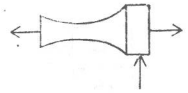
(*iv*) Pneumatic conveying		Used for handling grains, cement, powdered chemical, coke etc.	An air steam is used to affect the conveying.
3. SEPARATION PROCESSES			
(*a*) *Solid-solid separation*			
(*i*) Screening		Used to separate particle of different sizes.	Screens are made of steel wire or plastic.
(*ii*) Elutriation		Used to separate fines from the coarse particles.	The separation is accomplished by passing fluid counter currently to the feed material.
(*iii*) Jigging		Used to separate lighter gangues from heavy mineral. Materials of different densities can also be separated.	Terminal velocity of the particle significantly affects the separation of particles. Setting period is small.
(*iv*) Tabling		Used to separate more dense gold from less dense rock (*i.e.*, different density separation).	Separation is accomplished by passing a dilute pulp over a table inclined from the horizontal.
(*v*) Electrostatic separation		Used to separate small particle of different solids when placed in a electric field.	Separation occurs due to different behaviours in an electric field.

Unit Operation	*Schematic Representation*	*Application*	*Remarks*
(*vi*) Magnetic separation		Used to remove ions from feed to be used in the grinding.	
(*vii*) Froth floatation		Used to separate fines from coarse by floating the material on the surface of water. Also used to separate hulls of wheat from the kernel, KCl from sodium chloride.	Separation is achieved when the material is suspended in water in the presence of a floating agent and bubbling with air. The froth formed on the surface contains the desired material.
(*b*) *Fluid-solid separation*			
(*i*) Sedimentation (thickeners)		Used to separate sludges and supernatant liquid from dilute slurry: used in sewage effluent classification.	Separation is accomplished by introducing the dilute slurry at the centre of the tank and allowed to settle.
(*ii*) Cyclone separator		Used to separate solid particles (coarse size more effectively) and liquid droplets in suspension from the gases.	Separation is accomplished by introducing the stream tangentially giving suspension a spinning motion in the cylinder. Centrifugal force on the particle tends to separate them.
(*iii*) Electrostatic precipitator		Used to separate entrained solid or liquid particles from gases.	Separation is achieved by passing the gas between two electrods which attracts the entrained particles.

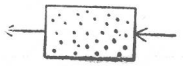
(*iv*) Bag filters		Used to separate solid particles from gas *e.g.*, air conditioning and home-heating systems.	Separation is achieved by passing the gas stream through a battery of bags mounted in groups on independent frames.
(*v*) Filter press		Used to separate solid material from the slurry, by passing the slurry through an assembly of plates and frames separated by a filter media *e.g.*, oil industry etc.	Separation is achieved by applying pressure and maintaining it throughout.
(*vi*) Rotary vacuum filter		Used to separate solid material from the slurry *e.g.*, paper industry: pulp fibre from water.	Separation occurs as a result of vacuum applied inside the drum which pulls the filtrate from the solid.
(*vii*) Centrifugation		Used to separate fine or coarse granular or crystalline solids from water or other fluids. Also liquids from liquid emulsions and liquids of different densities.	Centrifugal force is used to achieve the separation.
(*viii*) Settling tanks		Used to separate large size particles from the gas stream.	Separation is achieved by passing gas stream in low velocity zone.

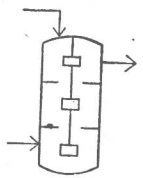
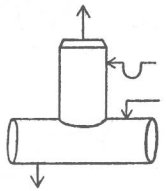
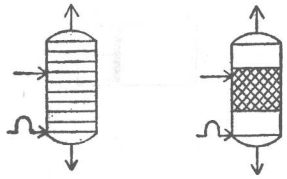
Unit Operation	*Schematic Representation*	*Application*	*Remarks*
(*ix*) Crystallization		Used to separate solid particles from their saturated solutions, *e.g.* sugar, inorganic salts are separated in this way.	Separation starts when hot and saturated solution is stirred and cooled resulting nucleation and crystal growth.
4. FLUIDIZATION			
(*i*) Fixed bed		Fluid solid contact process in fixed bed is used where solid is costly and its loss is to be minimised. Pellets of cylindrical and spherical sizes are generally used. Also where the heat losses are to be minimum.	The process is achieved in system in which the boundaries of the solid particles are fixed and the fluid is passed through the bed.
(*ii*) Fluidized bed		The process is used where the better fluid-solid contact is desired. Solids in finally divided form are used *e.g.*, catalytic cracking of oil, roasting of sulphide ore, gasification of coal etc.	The process is achieved by passing fluid through the bed of finally divided particles.
(*iii*) Moving bed		The type of process is used in the regeneration of catalyst in the catalytic reaction, in gasification of coal, it can utilize variety of coals.	The process is achieved by passing fluid through the bed. The bed moves as the fluid moves through it.

5. FLUID HANDLING

(*i*) Reciprocating pump or compressor		Used where high pressure fluid discharge is required. May be used for metering or proportioning.	The reciprocating machines deliver constant volume of fluid against a wide range of pressure and can be built to operate against high pressures.
(*ii*) Centrifugal pumps		Used to pump all types of fluids, corrosive liquids and liquid containing small solid particle in suspension.	Centrifugal force is used to transport the fluid.
(*iii*) Rotary pump		Used to handle, clear liquid dilute and concentrated stumics and pastes.	The rotating movement of the working part with the *position* displacement is the main characteristic in handling the fluid.
(*iv*) Jet ejector		Used for low pressure operation or production of vacuum. Steam is often used as motive fluid.	

6. EXTRACTION

(*a*) *Solid-liquid* (*leaching*)		Used to recover solid solute with the liquid solvent: Often used in ore treatment to recover metal *e.g.*, copper is recovered from oxidized copper ore.	In this process ore is contacted with the solvent either in single stage or multistage to recover the metal value.

Unit Operation	*Schematic Representation*	*Application*	*Remarks*
(*b*) *Liquid-liquid*		Used to recover liquid solute with the liquid solvent. The solvent must be insoluble in the solution to be extracted: Often used for the removal of naphthenic and aromatic from lubricating oil, acetic acid from dil. aqueous solution, recovery of penicillin etc.	The process is accomplished by contacting the solution to be extracted counter currently with the solvent to give extract containing solute and raffinate containing undesired material.
7. DISTILLATION			
(*a*) *Batch*		Used to handle small volume of feed and product.	The operation is carried out by introducing feed into the heated kettle fitted with a packed or tray tower and a condenser. Product is removed from the top.
(*b*) *Continuous*			
(*i*) Tray type: (*ii*) Packed type		Used to handle large volume of feed. Separate complex mixtures into their constituent *e.g.*, petroleum industry, alcohol industry etc.	The operation is carried out by introducing feed into the column and then separating more volatile at the top and less volatile at the bottom.