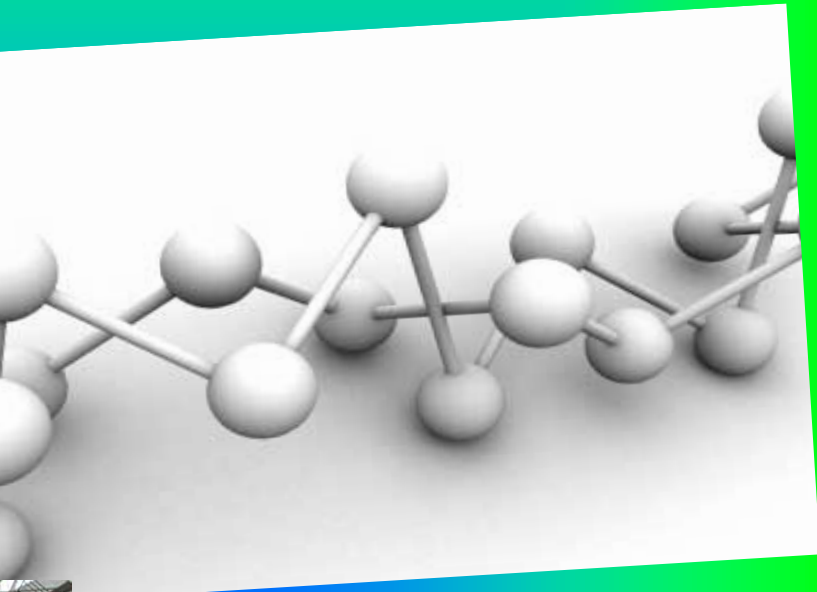


ORGANIC CHEMICAL TECHNOLOGY



I D MALL



Lecture 1

Chemical Process Industries

LECTURE 1

CHEMICAL PROCESS INDUSTRIES

INTRODUCTION

Chemical industry is one of the oldest industries and playing an important role in the social, cultural and economic growth of a nation and in providing basic needs of humankind - food, shelter and clothing have become an indispensable part of our life. [Figure M-I 1.1](#) illustrate the role of chemical industry in daily life. It is one of most diversified of all industrial sectors covering thousands of products. Chemical industry includes basic chemicals and its product, petrochemicals, fertilizers, paints & varnishes, gases, soap and detergent, perfumes, pharmaceuticals and covers thousands of products, which are finding use in our daily life from industrial to household goods. Structure of organic chemical industry is shown in [Figure M-I 1.2](#). Various products are finding use in various fields packaging to agriculture, automobiles to telecommunication, construction to home appliances, health care to personal care, explosive, pesticides to fertilizer, textile to tire cord, chemicals to pharmaceuticals [[Table M-I 1.1](#)].

Indian chemical industry plays an important role in the overall development of Indian economy and contributes about 3% in the GDP of the country. It comprises large scale, medium scale and small units.

The chemical industry is a key contributor to the world economy and produces more than 8000 products, which is a vital part of agricultural and industrial development in India and has key linkages with several other downstream industries such as automotive, consumer durables, engineering and food processing [[Chemical Engineering World, 2004](#)]. Organic chemicals are one of the important sectors of the Indian chemical industry, which provide a vital development role by providing petroleum products, chemical feedstock, basic chemicals, intermediates, and important products like polymer, synthetic fibre, synthetic rubber, paints, varnish, pesticides and explosives, dyes, specialty chemicals. Major feedstocks for chemical industries are coal, petroleum, biomass, oils and fats, sulphur, salt, lime stone, rock phosphate etc.

Table M-I 1.1: Major Products of Chemical Industries and their Area of Application

Group of Product	Areas
Plastics and Polymers	Agricultural water management, packaging, automobiles, telecommunications, health and hygiene, education
Synthetic rubber	Transportation Industry, Textile, Industrial equipment lining
Synthetic fiber	Non-oven and woven fibre in automobile , hosiery, textile
Soap and Synthetic detergents	Health and hygiene domestic as well as industrial
Industrial chemicals	Drugs & pharmaceuticals, pesticides, explosives, surface loading, dyes, lube additives, adhesive oil field, antioxidants, chemicals, metal extraction, printing ink, paints
Sugar & Alcohol	Food, Alcoholic Brewages, Chemical Feed Stock, Ethoxylate, biofuel
Pulp & Paper	Writing & Printing Paper, Culture Paper, News Printing Paper, Tissue Paper, Packaging Paper
Fertiliser	Agriculture, Chemical industry(ammonia and urea)
Agrochemicals	Pesticides
Mineral acids	Chemical industry- organic and inorganic

Sources: Mall, 2007

Chemical Industry

Food

Fertilizer & Agrochemical

Clothing

Synthetic fibers, Dyestuffs, Textiles, Auxiliaries, Specialty Chemicals

Shelter

Polymer composites, Coating, New Performance Materials

Health Care

Pharmaceuticals, Polymers, Synthetics, Detergent

Quality of Life

Transportation, Education, Fuel, Electricity, Energy, Water supply, Management, Communication, Polymers & Industrial Chemicals

Figure M-I 1.1: Role of Chemical Industry

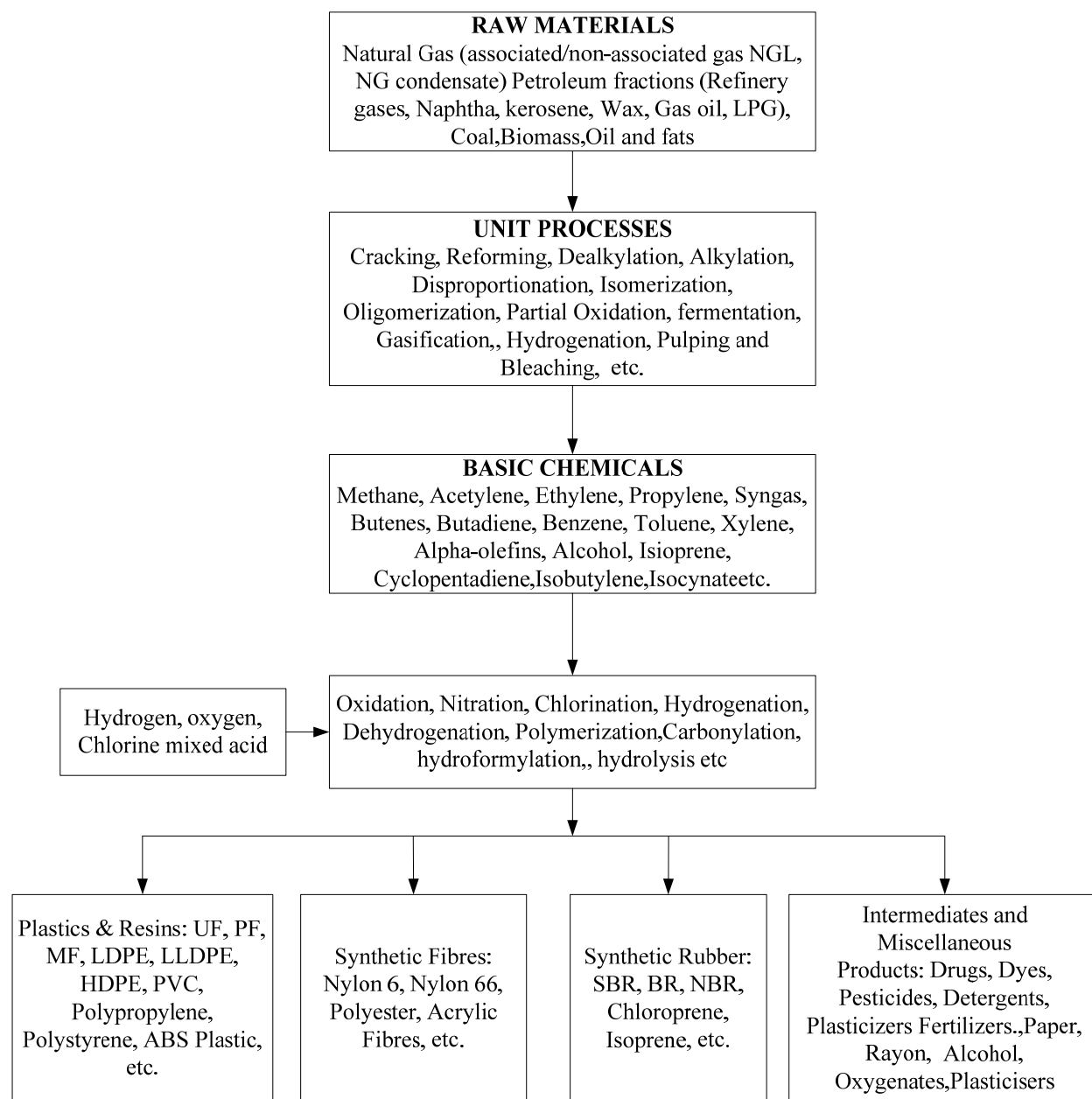


Figure M-I 1.2: Structure of Organic Chemical Industry

CHEMICAL INDUSTRY AND TECHNOLOGICAL DEVELOPMENT IN CHEMICAL INDUSTRY

Chemical process industry has evolved considerably over the last century largely in response to changing societal requirements and changing raw material availability and environmental issues.

Some of the major technological development in chemical industry are

- Leblanck process to Solvay and modified Solvay process

- Lead chamber to Contact process (single absorption and DDCA)
- Diaphragm process to Mercury and Mercury to Membrane
- Wet to Dry cement Process
- Coal chemicals to alcohol based chemicals to petroleum based chemicals and vice versa
- Acetylene based chemicals to other routes
- Claus to Super Claus process
- Wood based paper to agro-based and waste paper based
- Pulping to biopulping
- Stone ground wood pulping to thermo mechanical pulping
- Chlorine to oxygen bleaching and enzymatic bleaching
- Sulphur to pyrite based sulphuric acid plant
- Conventional aluminium and iron based catalyst to zeolite based catalyst
- Coal based Fertilizer to Natural gas and Naphtha based Fertilizers
- Coal and Alcohol based chemical to Petroleum based chemicals
- Thermal cracking to Catalytic cracking
- FCC to Deep catalytic cracking for olefin and Hydrocracking for processing heavier crude
- Naphtha reforming to isomerisation
- Acid catalyst to solid acid catalyst in alkylation process
- Naphtha steam cracking to gas cracking
- Conventional petroleum fuel to biofuel
- Coal as fuel to coal as chemical
- Coal gasification to Petrocoke and Biomass gasification
- Chemical pesticide to bio pesticide
- Chemical fertiliser to biofertiliser
- Soap to detergent, Non biodegradable detergent to Biodegradable detergent
- Natural gas to coal bed methane, shale gas, gas hydrate
- Dimethyl terephthalate(DMT) to Purified terephthalic acid(PTA)
- Conventional caprolactam to ammonium sulphate free caprolactam
- Natural fibre to Synthetic Fibre
- Natural rubber to synthetic rubber
- Petroleum refinery to Natural gas refinery and Biorefinery
- Petroleum refinery to Petrochemical refinery
- Conventional gasification to underground gasification
- Conventional drilling to horizontal drilling and hydrofracturing
- Gas to liquid and Methanol to olefin technology
- Coal to methanol and olefin
- Conventional desulphurization to ultra desulphurization processes and biodesulphurisation

- Polymer to biopolymer
- Conventional Ziegler Natta catalyst to metallocene catalyst

GLOBAL AND INDIAN CHEMICAL INDUSTRIES

The chemical industry is one of the world largest sectors of economy. In 2008, its sales exceeded 3 trillion USD and more than 20 million people around the global have job connected to chemical industry. [Figure M-I 1.3](#) give details of world chemical market.

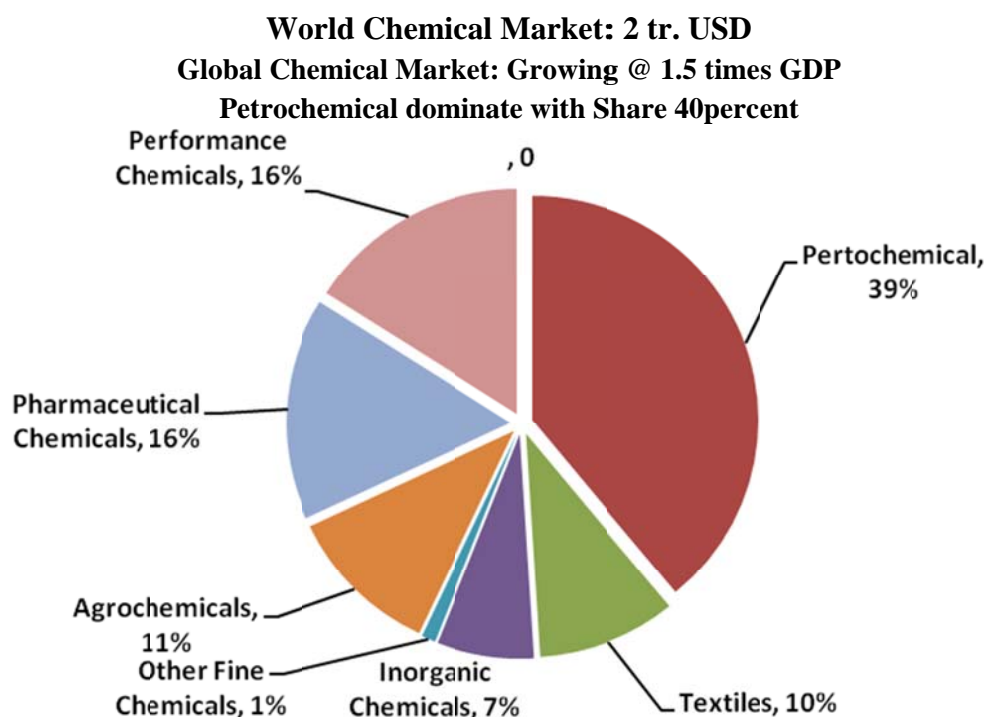


Figure M-I 1.3: World Chemical Market

Sources: Nanvaty, 2008

Indian chemical industry is an important constituent of the Indian economy. Its size is estimated at around US \$ 35 billion approx. which is equivalent to about 3% of India' GDP. The total in Indian Chemical industry is approx. 60 billion and total employment is about 1 million. The Indian chemical sector accounts for 13-14% of total exports and 8-9% of total imports of the country. Export of chemicals and related products was 24.066 billion USD in 2008-9 accounting to 13.63 of total imports. In terms of volume, it is 12th largest in the world and 3rd largest in Asia. Currently per capita consumption of products of chemical industry in India is about 1/10th of the world average. Over the last decade, the Indian chemical industry has evolved from being a basic

chemical producer to becoming and innovative industry. Driving force for development of chemical industry is given in [Table M-I 1.2](#) with investments in R&D, the industry is registering significant growth in the knowledge sector comprising of specialty chemicals, fine chemicals and pharmaceuticals with annual growth rate over 10%. The total production of organic chemicals during 2008-09 works out to 1.25 million with value of 0.9717 billion. The size of the petrochemicals segment was estimated at 13.96 billion. Total size Dyestuff industry is estimated 4 billion USD. There are 50 organized industries and over 900 small-scale industries. India has 8.5-9% global market share. The India pharmaceutical industry is the fourth largest volume terms and 15th largest market in value terms. The market will reach 20 billion USD by 2015 and 30 billion USD by 2020. The size of the Agrochemicals industry estimated at over 1billion USD. Fertiliser capacity N and P as (P₃O₅) is 12.29 and 10.90 million tones and production 10.9 and 3.40 million tones respectively. The turnover during 2008-09 was around 28.49 USD. Chemical and fertilizer sector in India presently constitutes 14% of the domestic industrial activity [[Lokhapare, 2011, Annual report 2010-11](#)]. Segments of the Indian chemical industry are given in [Table M-I 1.3](#). Details of major chemical production and growth are shown in [Table M-I 1.4](#).

Table M-I 1.2 Driving Force Indian Chemical Industry

Surface Area : 3.287 Million Km²
 Population : 1. 2 Billion
 Coastline : 6,000 km
 Port traffic : Over 350 Million TPA
 Road Length : Over 3 Million Km
 Railways : 100,000 Track Km
 (Largest in Asia, 2nd in the World)

Growth of Population 1951 : 36 Crore To present 130 Crore

Growth in vehicle population: more than five fold

India's passenger vehicle production projections :

In 2010 – 2.6 million Vehicles

By 2015 – 5.1 million Vehicles

By 2020 – 9.7 million Vehicles

Contribution of GDP by: Agriculture: 25%, Industry: 24% Services: 51%

Table M-I 1.3: Segments of the Indian Chemical Industry

Basic Chemicals (49.05%): Market value:32.78USD

- Inorganic chemicals:(Caustic chlorine, soda ash, sodium bicarbonate, carbon black, titanium oxide, sulphuric acid, hydrochloric acid etc.)
- Organic chemicals(acetic acid, acetic anhydride, acetone, phenol, methanol, formaldehyde, nitrobenzene, malice anhydride, aniline, chloromethanes, acetaldehyde, ethanol amines, ethyl acetate etc.
- Petrochemicals(Olefins, aromatics-benzene, toluene, xylenes, fibre intermediates MEG, PTA, acrylonitrile, propylene, caprolactam, adipic acid, hexamethylene diamine, phthalic anhydride, methanol, LAB, polymers, synthetic fibre, etc)
- Fertilizers(Nitrogenous and Phosphatic)
- Other industrial chemicals

Specialty Chemicals (24.69%): Market value:16.50USD

- Paints and varnishes,
- Textile chemicals
- Dyestuffs and intermediates
- Catalysts
- Plastic additives
- Adhesive sealants
- Industrial gases

Knowledge Chemicals (26.6%): Market value:17.55USD

- Pharmaceuticals
- Biotechnology
- Agrochemicals

Source: [Lokhapare, 2011]

Table M-I 1.4: Product-wise Production of Major chemicals

Major Chemical Products	Production 2010-11 in 000' MT
Alkali Chemicals	
Caustic soda	2178.45
Chlorine	1503.99
Soda ash	2298.75

Total alkali chemicals	5981.19
Inorganic chemicals	
Aluminium chloride, Calcium carbide, Carbon black, Potassium chlorate, Titanium oxide, Red phosphorous	
Total	572.04
Pesticides and Insecticides	1341.75
Dyes and Dyestuff	8023.54
Organic Chemicals (Acetic acid, Acetic Anhydride, Acetone, phenol, Methanol, Formaldehyde, Nitrobenzene, Maleic anhydride, Penta-erithritol, Aniline, Chloromrthanes, Isobutylene, MEK, ONCB,PNCB, Acetalldehyde, Ethanolamines, Ethyl acetate, nitrotoluene)	1341.76
Aromatics	
Benzene	945
Mixed xylene.	44
Orthoxylene	400
Toluene	128
Paraxylene	2137
Total	3654
Synthetic Fibres (Acrylic , Polyester, Nylon, Polypropylene , fibrere	1169
Polymers (Polyethylene, Polypropylene, Polystyrene, Poly vinyl chloride)	5292
Elastomers (Styrene butadiene rubber, Polybutadiene rubber, Ethylpropylene dimmers, Ethyl vinyl acetate, Nitrile rubber)	94
Synthetic Detergent Intermediates	
LAB	475
Ethylene oxide	164
Performance Plastics (ABS resin, Polymethyl methacrylate(PMMA), Styrene acrylonitrile(SAN), Nylon	192
Fibre Intermediates (Acrylonitrile, Caprolactam, Dimethyl terephthalate, Monoethylene glycol, Purified terephthalic acid)	4098
Olefins , Ethylene, Propylene, (Butadiene)	4837
Aromatics (Benzene, Toluene, Mixed xylene, Ortho xylene, Para xylene)	3654
Other petro based chemicals (Butanol,C ₄ raffinate, diethylen glycol, Diacetone alcohol, 2-ethyl hexanol, methylemetha acrylate, Phthalic anhydride, Propylene oxide, Propylene	512

glycol, polyvinyl acetate resin, vinyl acetate monomer)	
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Source: Annual report 2011-2012 Department of Chemicals & Petrochemicals (Ministry of Chemicals & Fertilizer)

Chemical Feed Stocks: Past, present and future feedstock for chemical industry is mention below. Details of these raw material have been discuss in Lecture 2

PAST	PRESENT & FUTURE
➤ Coal, Salt, Biomass, Natural rubber, cotton,	➤ Gaseous: Natural Gas, Condensate, Refinery Gases, Coal Bed Methane, Gas Hydrate, Shale gas ➤ Liquids : Naphtha, Solvent Extracts, Middle Distillates ➤ Solids : Coal, Coke, Wax, Residues ➤ Biomass: Agriculture residue, Algae ➤ Sea Chemicals: Salt, Bromine, Iodine, Titanium, Zirconium etc More> 64 elements

Characteristic of the Indian Chemical Industry [Lokhapare, 2011]

- High domestic demand potential as the Indian markets develops and per capita consumption levels increases.
- High degree of fragmentation and small scale of operations
- Limited emphasis on exports due to domestic market focus
- Low cost Competitiveness as compared to other countries due to the high cost of feed stocks and power
- Low focus on R & D despite initiatives to innovate processes to synthesis products effectively

INDIAN CHEMICAL INDUSTRY WEAKNESSES: Although Indian chemical industry has made consistent growth during last six decades, however, compare to global level there is lot of scope for further development. Some of the weaknesses are

- Sizes of older units well below global levels
- High cost structures
- Higher cost of raw materials
- Long gestation periods
- Integration and infrastructure inadequacies

- Process development, Low R &D investment
- Mindset

TYPICAL ISSUES FOR CHEMICAL INDUSTRIES

Due to various technological and engineering developments, chemical industry has been able to reduce the cost of production. Changes in technology and raw materials have shifted regularly and frequently towards Lower costs and competitive, Better conversion and efficiency, high productivity, less energy consumption, Broader spectrum of product grades. However, due to increasing cost of raw materials and stringent environment issues, chemical industry is facing major challenges in future. Typical issues in chemical industry to meet the future challenges are shown in [Figure M-I 1.4](#).



Figure M-I 1.4: Typical Issues in Chemical Industry

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