

15CH210 Chemical Process Technology

Unit 5 - Synthetic Organic Chemicals

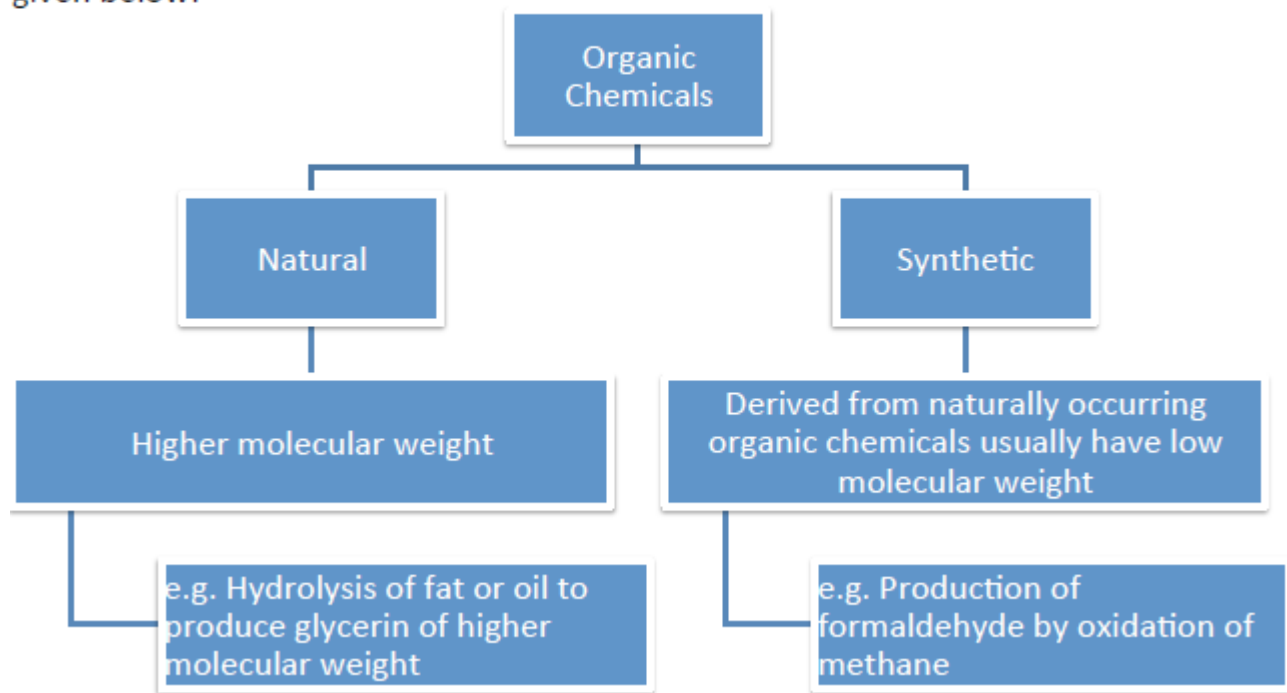
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Unit 5 Synthetic Organic Chemicals

- Organic and Synthetic Chemicals - an Overview
 - Definition of Cracking and Reforming
 - Methane and synthesis gas
 - Ethylene, acetylene and propylene.
 - Plastics (Thermoplastics and Thermosetting resins)
 - Polyethylene and Polypropylene
 - Polymers and their engineering applications
 - Polyamides, polyesters and acrylics from monomers
 - Manufacture of Viscose Rayon
 - Processes for the production of natural and synthetic rubber
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Unit 5 Synthetic Organic Chemicals - An Overview

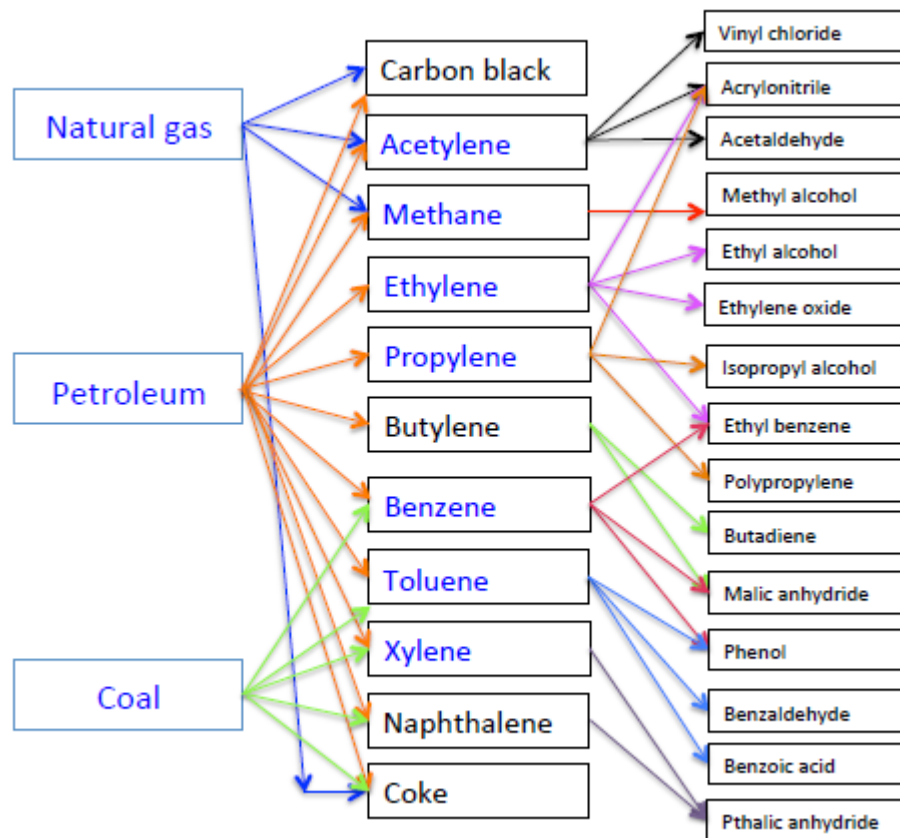
Organic Chemical is a compound containing carbon, oxygen and hydrogen as principal constituent elements. These compounds are classified based on their occurrence as given below:



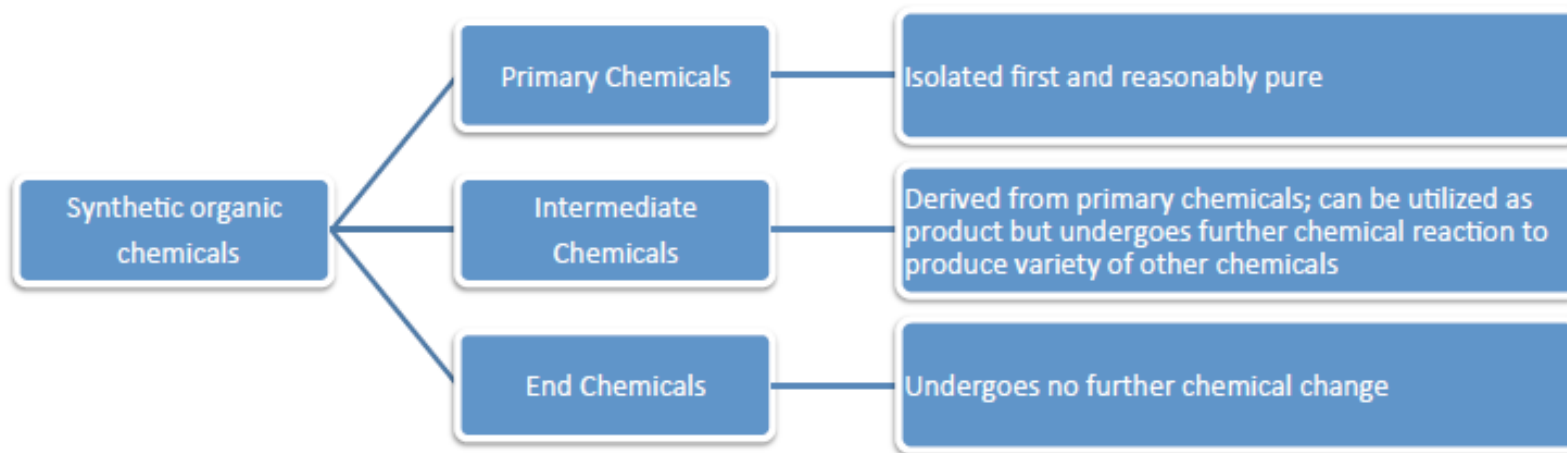
Unit 5 Synthetic Organic Chemicals - An Overview

S. No	Natural Source (or) Raw material	Process	Product
1.	Natural gas (largely of methane and relatively small amount of ethane]	Cracking	Methane, Ethane, Propane and Butane
2.	Liquefied Petroleum Gas - LPG (Propane and Butane]	Cracking	Olefins or Alkenes such as Methylene, Ethylene, Propylene and Butylene
3.	Refinery off gas	Catalytic cracking and reforming operations	Paraffins and Olefins
4.	Petroleum feed stock	Hydroforming	Benzene, Toluene and Xylene
5.	Naptha and fuel oil	Steam reforming or catalytic reforming	Synthesis gas, ethylene, and acetylene
6.	Petroleum coke	Cracking	Acetylene which is used as electrodes in aluminum industry

Unit 5 Synthetic Organic Chemicals - An Overview



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Unit 5 Synthetic Organic Chemicals - An Overview

Primary Chemical	Intermediate chemicals	End Chemicals	Uses
I. Methane	1. Methyl Chloride		Silicones
	2. Methylene Chloride		Paints, Freon
	3. Chloroform		Freon, Anesthesia
	4. CCl ₄		Freon, dry cleaning, adhesive solvent
	5. Carbon disulfide		Viscose rayon, cellophane tape
	6. Mercaptants		Odorants, fumigants
	7. Hydrogen cyanide	(a) Sodium cyanide	Fumigants
		(b) Acrylonitrile	Synthetic fiber
		(c) Methyl methacrylate	Sheets for signs, Moldings
	8. Acetylene	(a) Vinyl acetate [polyvinyl acetate]	Adhesives, Paint emulsions
	(b) Trichloro ethylene	Metal degreasing	
	(c) Welding	Metal working	
	(d) Acrylate	Paint emulsions, Textile treatments	
	(e) Acrylonitrile	Synthetic fibers	
II. Synthesis Gas	1. Ammonia	(a) Nitric Acid	Explosives (Nitroglycerin, Dynamite)
		(b) Ammonium Nitrate	Fertilizers
		(c) Tri Nitro Toluene (TNT)	Explosives
		(d) Ammonium Sulfate	Fertilizers
		(e) Urea	Fertilizers
	2. Methanol	(a) Formaldehyde	Adhesives, Laminates, Coatings
		(b) Methacrylate	Sheets for signs, Moldings
		(c) Methyl Chloride	Silicones
	3. Carbon dioxide		Beverages, Dry ice

Unit 5 Synthetic Organic Chemicals - An Overview

Primary Chemical	Intermediate chemicals	End Chemicals	Uses
III. Ethylene	1. Ethanol	(a) Acetaldehyde	Fibers, Films, Moldings
		(b) Acetic Acid	Adhesives, Paint Emulsions
		(c) Esters	Lacquers, Coatings
		(d) Solvents	Solvents, Coatings
		(e) Ethyl Alcohol	Food and Beverages
	2. Ethylene oxide	(a) Glycol	Anti freezer
		(b) Polyesters	Polyurethanes (Foams)
		(c) Ethanol amines	Shampoo, Floor wares
		(d) Acrylonitrile	Synthetic fibers
	3. Ethyl chloride	(a) Vinyl chloride (PVC)	Film sheets, Fabrics, Pipes, wires
	4. Poly ethylene		Packaging films, Pipes and Wire
	5. Styrene	(a) S - type rubbers	<u>Tyres</u> and rubber goods
		(b) S - type latex	Paints, Paper coatings
		(c) Reverse ratio rubbers	Shoe soles, Luggage's
		(d) Polystyrene	Housewares, Tiles, Packaging

Unit 5 Synthetic Organic Chemicals - An Overview

Primary Chemical	Intermediate chemicals	End Chemicals	Uses
IV. Propylene	1. Methanol	(a) Formaldehyde	Molding, Textiles, Adhesives
		(b) Solvents	Solvents
		(c) Esters	Coatings, Solvents
		(d) Methacrylate	Sheets of signs, Moldings
		(e) Methyl Chloride	Silicones
	2. Acetaldehyde	(a) Vinyl acetate	PVC, Adhesives, Paint Emulsions
		(b) Butyraldehyde	Plasticizers
		(c) Cellulose acetate	Fibers, Films, Moldings
	3. Propylene tetramer	(a) Dodecyl benzene	Detergents
		(b) Caprolactum	Nylon
	4. Cumene	(a) Phenols	Resins
		(b) Acetone	Solvents
	5. Isopropanol	(a) Hydrogen peroxide	Bleaching agents in paper industries
		(b) Glycerol	Soap manufacturing
	6. Propylene oxide	(a) Polyurethanes	Foams
	7. Acrylonitrile		Fibers, Resins
	8. Isoproprene	(a) Polyisoprene	Synthetic rubber products

Unit 5 Synthetic Organic Chemicals - An Overview

Primary Chemical	Intermediate chemicals	End Chemicals	Uses
V. Benzene	1. Styrene	(a) S- type rubber	Tyres, Rubber goods
		(b) S- type latex	Paint emulsions, Paper coatings
		(c) Reverse ratio rubber	Shoe soles, Luggage
		(d) Polystyrene	Housewares, Packaging, Tiles
	2. Dodecyl benzene	(a) Dodecyl benzene sulfonate	Detergents
	3. Phenol	(a) Caprolactum	Resins, Nylon
	4. Malic anhydride		Insecticides
VI. Toluene	1. Solvent		Coatings
	2. Benzoic acid	Sodium benzoate	Food preservatives
	3. Dichlorotoluene	Diisocynate	Polyurethanes foam
VII. Xylene	1. o - Xylene	Phthalic anhydride	Plasticizers, Polyesters
	2. m - Xylene	Isophthalic acid	Plasticizers
	3. p - Xylene	Terephthalic acids	Polyesters

Cracking

Break down of large hydrocarbon molecules into smaller molecules by heat or catalytic action.

Thermal decomposition of organic compounds is known as *pyrolysis*; pyrolysis when applied to alkanes is known as cracking

Reforming

The process whereby straight-run gasoline is cracked in order to raise the octane number.

Unit 5 Synthetic Organic Chemicals - Methane and Synthesis gas

Methane

Methane occurs in “natural gas” and the gases from oil wells.

Methane is the principal product of organic decay in swamps and marshes.

Sewage sludge which has been fermented by bacteria yields a gas containing about 70% methane and this is used as liquid fuel.

Uses

Methane can be used to prepare

1. carbon black
 2. make paints and printers ink
 3. rubber for motor tyres
 4. synthesis gas
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Unit 5 Synthetic Organic Chemicals - **Synthesis gas**

Synthesis gas (CO, H₂)

Synthesis gas is generally considered to be a variable mixture of CO and H₂ for synthesis of organic compounds.

Uses

H₂ obtained from the synthesis gas has many uses in hydrogenation

The mixture (CO and H₂) is used in methanol synthesis

Used in the synthesis of hydrocarbons by Fisher-Tropsch process

Used in the ammonia production

Used to produce acetic acid.

Unit 5 Synthetic Organic Chemicals - Manufacture of **Synthesis gas**

Synthesis gas (CO, H₂)

Synthesis gas is generally considered to be a variable mixture of CO and H₂ for synthesis of organic compounds.

Methods of production

1. From petroleum hydrocarbon – Reforming and Partial Combustion
2. From coal – Cracking

Chemical reactions (Reforming process)

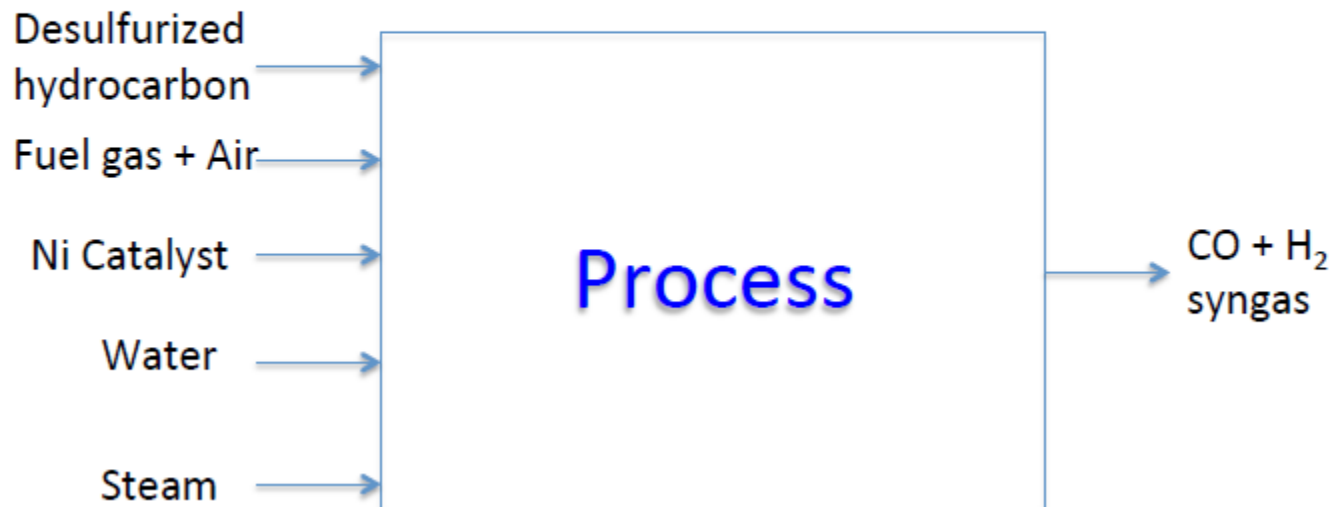


$n = 1, \Delta H^\circ = +52 \text{ kcal}; n = 2, \Delta H^\circ = +238 \text{ kcal}$ (Endothermic)

Unit 5 Synthetic Organic Chemicals - Manufacture of **Synthesis gas**

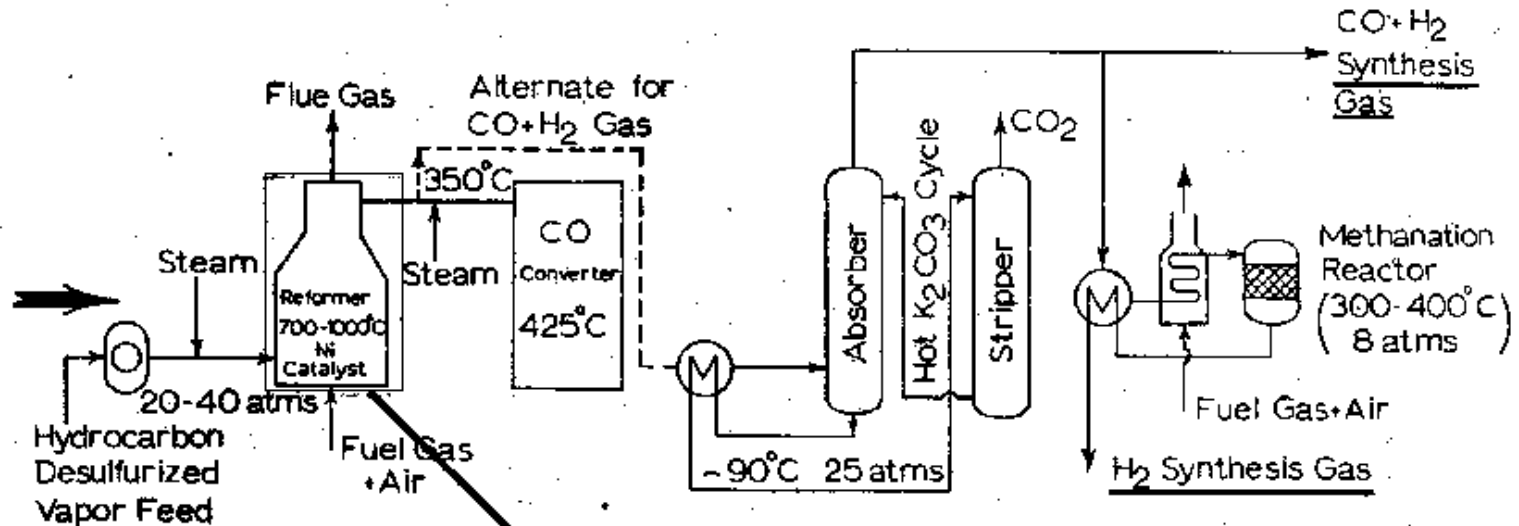
Steam Reforming of Petroleum Hydrocarbons

Process



Unit 5 Synthetic Organic Chemicals - Manufacture of **Synthesis gas**

Steam Reforming of Hydrocarbons



Catalyst packed: Ni
Vertical tube length: 20 – 25 ft
Space Velocity: 500 – 600/h
Reaction : Endothermic

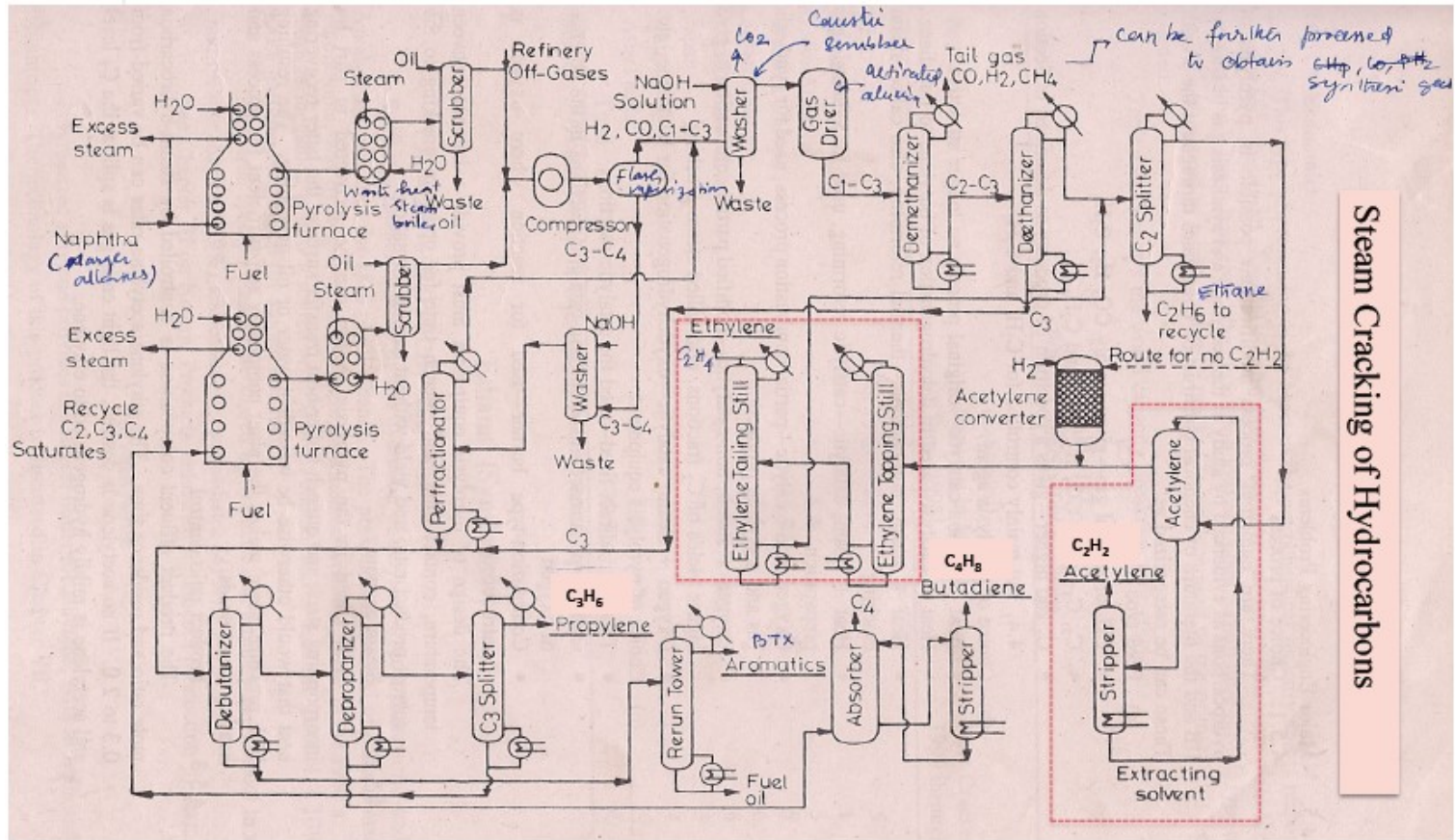
Unit 5 Synthetic Organic Chemicals - Manufacture of **Synthesis gas**

Process	Equipment	Unit Operation	Unit Process	Objective	Operating Conditions
Continuous	Compressor	Fluid transportation	-----	Compress the feed with steam and transport the feed into the reformer furnace	20 – 40 atm
Continuous	Reformer furnace	-----	Reformation or Combustion	Combustion of the mixed hydrocarbon feed in presence of nickel catalyst. The reaction is highly endothermic Ni $(a) \text{C}_n\text{H}_{2n+1} + n\text{H}_2\text{O} \rightleftharpoons n\text{CO} + (2n+1)\text{H}_2;$ $\Delta H^\circ = + 52 \text{ kcal for } n=1$ $\Delta H^\circ = + 238 \text{ kcal for } n=6 \text{ (Endothermic)}$ $(b) \text{CO} + 3\text{H} \rightleftharpoons \text{CH}_4 + \text{H}_2\text{O}$ $\Delta H^\circ = - 9.806 \text{ kcal (Exothermic)}$	Catalyst packed: Ni Vertical tube length: 20 – 25 ft. Space Velocity: 500 – 600/h Reaction: Endothermic
Continuous	CO converter Water -gas shift convertor	-----	Reformation	Remove CO from hydrocarbon mixture	-----
Continuous	Absorber	Gas – Liquid separation	-----	To separate synthesis gas (or syngas) by adding K_2CO_3	-----

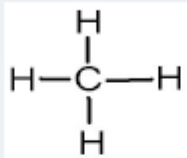
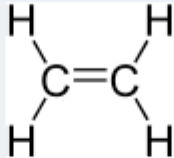

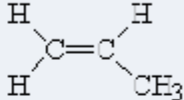
Unit 5 Synthetic Organic Chemicals - Manufacture of **Synthesis gas**

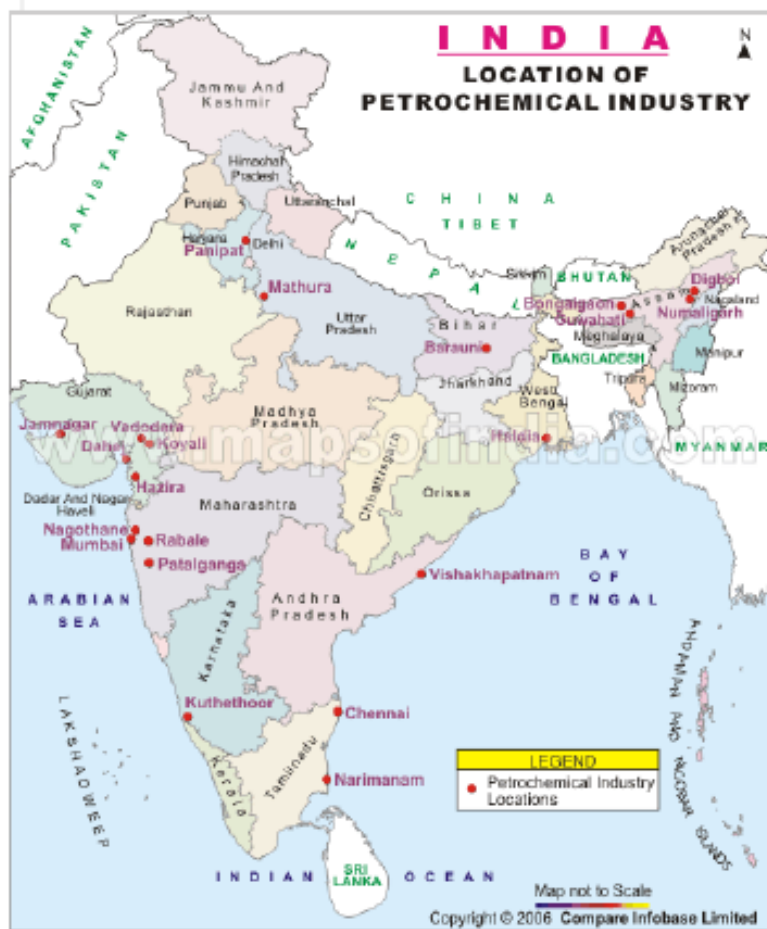
Process	Equipment	Unit Operation	Unit Process	Objective	Operating Conditions
Continuous	Stripper	Gas - Liquid Separation	-----	To separate the carbon dioxide in	-----
Continuous	Methanation reactor (Packed bed)	-----	Methanation	To produce pure hydrogen gas	-----

Unit 5 Synthetic Organic Chemicals - Ethylene, acetylene and propylene



Unit 5 Synthetic Organic Chemicals - Ethylene, acetylene and propylene

Compound	Methane	Ethylene	Acetylene	Propylene
Formula	CH ₄	C ₂ H ₄	C ₂ H ₂	C ₃ H ₆
Structure				
Properties	colorless, odorless gas, flammable	odorless, colorless gas	colorless gas, flammable distinctive odor	Colorless gas with distinctive odor
Uses	In the manufacture of <ul style="list-style-type: none"> • Fuel • Chloromethane • Dichloromethane 	In the manufacture of <ul style="list-style-type: none"> • Ethylene dichloride • Vinyl chloride • Ethylene dioxide 	In the manufacture of <ul style="list-style-type: none"> • Oxyacetylene gas welding and cutting • Polyacetylene • Acetaldehyde 	In the manufacture of <ul style="list-style-type: none"> • Propanol • Acrylonitrile • Acetone



Kochi Refineries

Hindustan Petroleum Corporation, Vizag

Mathura Refinery

Mangalore Refinery

CPCL, Chennai

Reliance Industries

Essar Oils

Reference s

1. Dryden C. E, *Outlines of Chemical technology – for the 21st Century*, 3rd edition, East-West Press (2004)
2. Austin G. T, *Shreve's Chemical Process Industries*, 5th edition, Mc Graw Hill International editions (1984)
3. Finar IL, *Organic Chemistry Vol. 1* 6th Edition Pearson Education 2009 pp.116-117