SUMMER-19 EXAMINATION

Model Answer

Subject title: Petrochemical Technology Subject code 17651

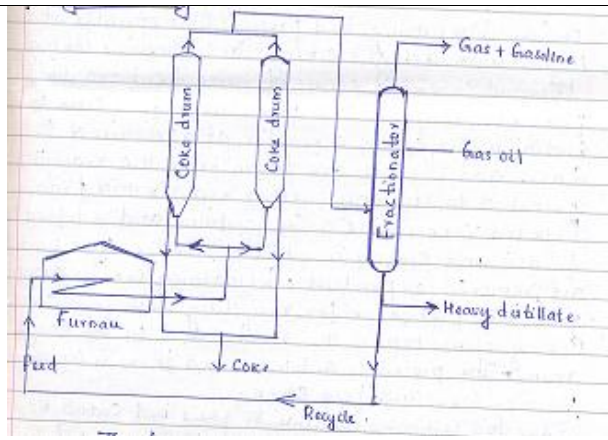
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q No.		Answer	Marking scheme
1 a		**Attempt any THREE of the following**	**12**
1a	i	**Countries producing crude oil with their percentage share (any six)** 1. Russia- 13.8% 2.United States -9% 3. China-5% 4. Canada- 4% 5. Gabon - 1% 6. Kuwait -3.5% 7. Ecuador - 1% 8. Libya- 1.9% 9. Equatorial Guinea - 1% 10. Nigeria – 2% 11. Qatar – 2.5 12. UAE – 4.2% 13. Venzuela -2.8% 14. Angola – 1% 15. Algeria – 1.8% 16. Iran - 4.14% 17. Iraq – 5% 18. Saudi Arabia-13%	4
1a	ii	**Reasons for considering distillation as a major unit operation in refining process:** Crude oil is a mixture of hydrocarbons with different boiling temperatures. By distillation it can be separated into different fractions with specified boiling range. Distillation of crude takes place in two stages- First stage(atmospheric distillation) and second stage (vacuum distillation)	4
1a	iii	**Emission control in petrochemical industries (four methods):** 1. Control of emission from refinery process gases: H_2S and mercaptans from process gases (normally used as fuel on fired heaters and boilers) are removed by scrubbing the gases with an absorption solvent such as aqueous amine solution.	1 mark each

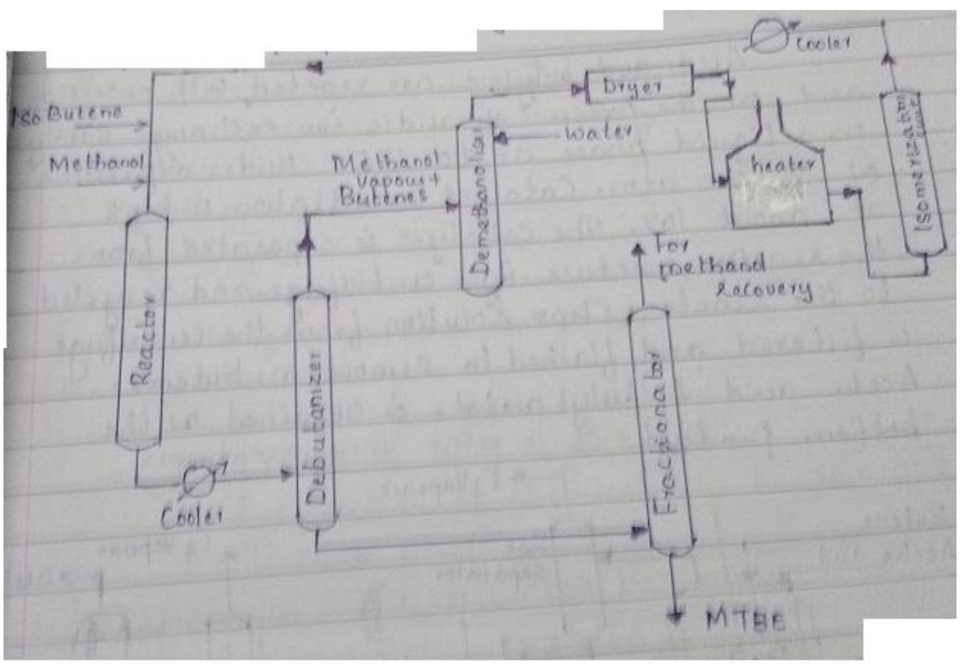
		2.Control of emission from fuel combustion: Emissions from fuel combustion can be controlled by changing the fuel type (switching to a cleaner fuel) or improving fuel oil quality (treating the fuel prior to combustion for removing polluting substances). 3. Control of emission from catalyst regeneration: An external cyclone separator or electrostatic precipitator is used before discharging the flue gas to atmosphere. Hydrocarbons emitted are completely consumed where cracking units are equipped with CO boilers. 4. Control of emission in storage: This is achieved by the use of floating roof or pressure storage for light hydrocarbons. 5. Control of emission by dispersion: This is done by providing taller stacks. 6. Control of emission through reduction of hydrocarbon losses: Hydrocarbon losses can be reduced by i) reducing flare loss ii) maximization of gas consumption in furnace/ boilers by proper coordination between gas producing and consuming units. iii) Installation of vapour recovery system while loading LPG in big wagons. iv) Proper and timely maintenance. 7. Sulphur recovery: The classical method of sulphur recovery is the claus process. This process is based on producing elemental sulphur, by first converting 1/3 of the H_2S to SO_2 and using this to combine with the remaining H_2S in the presence of a catalyst to form sulphur.	
1a	iv	**Chemicals derived from C1 hydrocarbon** 1. Methanol 3. Formaldehyde	½ mark

		2. Chloromethane 4. Methylene dichloride **Chemicals derived from C2 hydrocarbon** 1. Ethanol 3. Ethylene oxide 2. Styrene 4. Acetaldehyde: ***(Due consideration should be given for any other chemical derived from C1 and C2 hydrocarbon)***	each ½ mark each
1b		**Attempt any ONE of the following**	**06**
1b	i	**Description of thermal cracking process:** Thermal cracking is a refining process in which heat (˜ 800^{o}C) and pressure (˜ 700kPa) are used to break down, rearrange hydrocarbon molecules. Visbreaking, steam cracking, coking are applications of thermal cracking. **Delayed coking** In this method the heated charge is transferred to large coke drums which provide the long residence time needed to allow the cracking reactions to proceed to completion. Initially the heavy feedstock is fed to a furnace which heats the residuum to high temp.(480-510^{o}c) at low pressures (25-30 psi) and is designed & controlled to prevent premature coking in the heater tubes. The mixture is passed from the heater to one or more coker drums where the hot materials is held for 24 hours until it cracks into lighter products. Vapours from the drums are returned to a fractionator where gas, naphtha separated out.	2 2

<table>
<tr><td></td><td></td><td>


(Due weightage should be given for visbreaking, steam cracking,continuous coking etc)
</td><td>2</td></tr>
<tr><td>1b</td><td>ii</td><td>
Manufacturing of MTBE

Flow sheet:



MTBE is produced by the addition reaction between methanol and butylene
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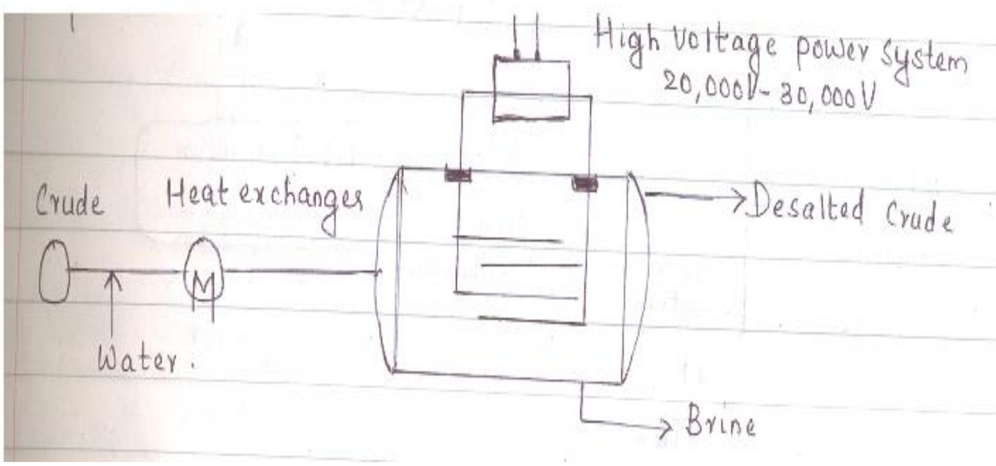
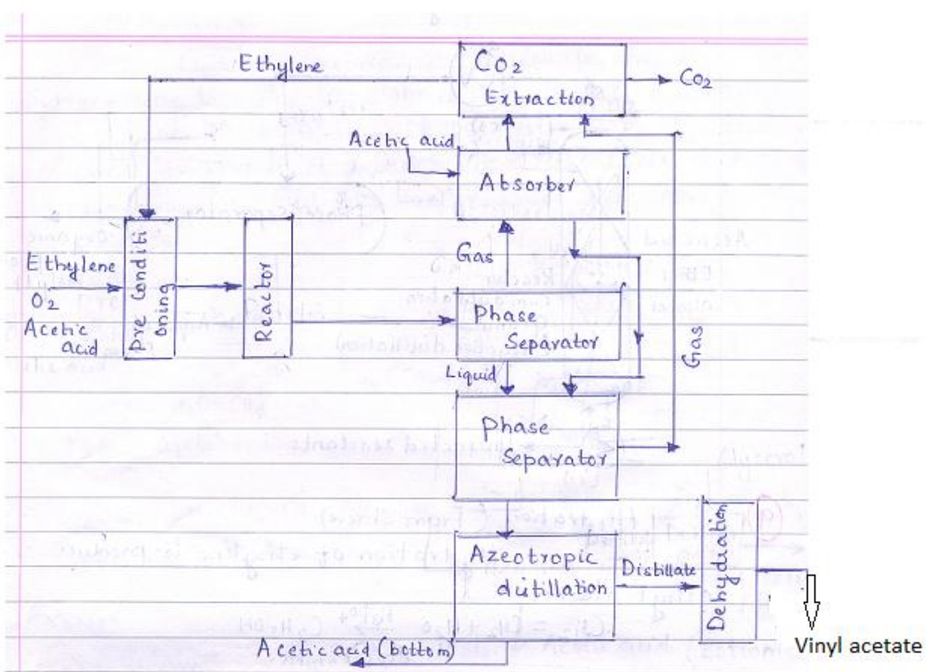
		Reaction: $(CH_3)_2C= CH_2 + CH_3OH \rightarrow (CH_3)_3CO\text{-}CH_3$ Isobutene and methanol enters a fixed bed reactor, where 90% of butene is consumed. The products are cooled to 20^0C, whereby unreacted methanol and MTBE are condensed. Butenes are separated first from the reactor mix by distillation (debutanizer). Methanol and MTBE mixture is obtained from the bottom of the column which is again distilled in a separate column to obtain MTBE as the bottom product. The gas phase containing methanol vapours is washed with water in a demethanolizer, dried, heated to about 300^oC and admitted to an isomerization unit where 2 and n-butene are converted into isobutene. Isobutene is cooled and then recycled.	3
2		**Attempt any FOUR of the following**	**16**
2	a	**Reason for crude oil being known as black gold:** Crude oil is yellowish black oil that is extracted from under the surface of the earth. It is one of the most necessitated worldwide required commodities. Any fluctuation in the crude oil prices can have direct and indirect influence on the economy of the countries. That is why crude oil is called black gold.	2
		Advantages of crude oil over other energy sources: 1. It is one of the most abundant energy resources. 2. Liquid form of oil makes it easy to transport and reuse. 3. Oil has high heating value. 4. No new technology needed for use.	½ mark each for any two pints
		Disadvantages of crude oil over other energy sources: 1. Oil burning leads to carbon emission. 2. Oil recovery process not efficient enough. 3. Oil drilling endangers the environment and ecosystem	½ mark each for any two pints

		4. Oil transportation by ships can lead to spills causing environmental and ecological damage.	
2	b	**Desalting of crude oil:** Desalting of crude oil is the removal of corrosive salts and water from the crude which will otherwise cause corrosion, plugging & catalyst poisoning. **Electric desalting:** The feedstock crude is heated between 150^0& 350^0F to reduce viscosity & surface tension for easier mixing & separation of the water. The principle of operation is that under a charged electric field, the polar molecules orient. A potential of 20,000-30,000 volts is applied between electrodes through which crude is passed. Water present in the form of emulsion also coalesces and agglomerates into a stream entrapping all the salts in the process. Brine collects at the bottom of the desalter, while crude floats above and forms a separate stream.  	4
2	c	**Esterification process:** **Reaction:**	

<table>
<tr><td></td><td></td><td>Vinyl ester is made by the esterification of olefins. Vinyl acetate is made by reacting ethylene with acetic acid in the vapour phase over a supported palladium catalyst.
$CH_2=CH_2 + CH_3COOH + 1/2\ O_2 \rightarrow CH_3COOCH=CH_2 + H_2O$
Description:
Reaction takes place in a fixed bed tubular reactor at 175-200^{0}c and 400-1000KPa and is highly exothermic. Effluent from the reactor is sent to a phase separator and the phases are separated. In the absorber the gas is washed with acetic acid to recover the vinyl acetate.

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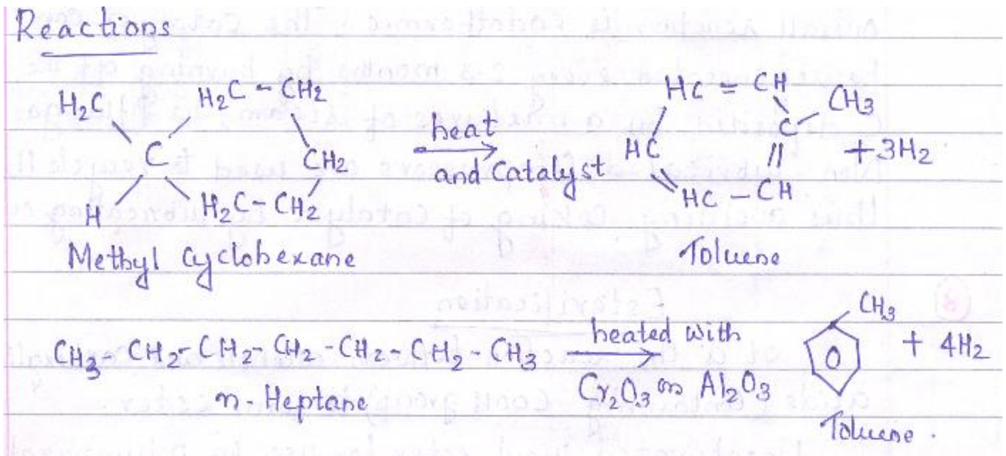
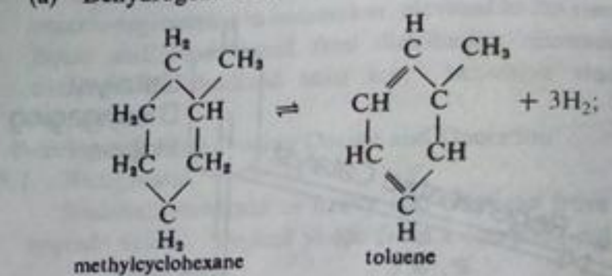
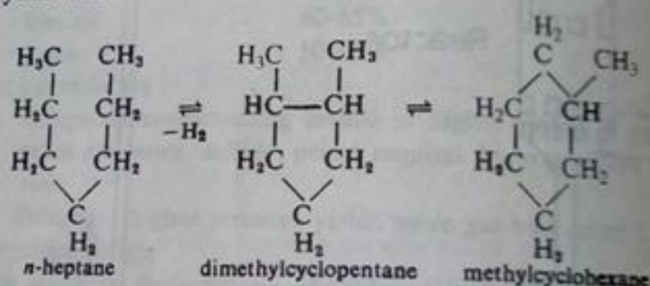
2</td></tr>
<tr><td>2</td><td>d</td><td>Reforming process
Principle:
Reforming is used to convert hydrocarbons to aromatics which have high</td><td></td></tr>
</table>

		octane rating. Reforming is an important process used to convert low octane naphtha into high octane gasoline blending components called reformates. Reforming represents the total effect of numerous reactions such as cracking, polymerization, dehydrogenation, isomerization taking place simultaneously.	2
			2
		Catalyst: Platinum Pressure: 15-50 atms Temperature: 470-525^{0}C	
		OR	

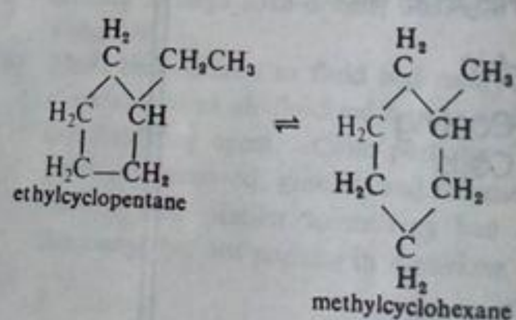
(a) Dehydrogenation (endothermic)



(b) Cyclization

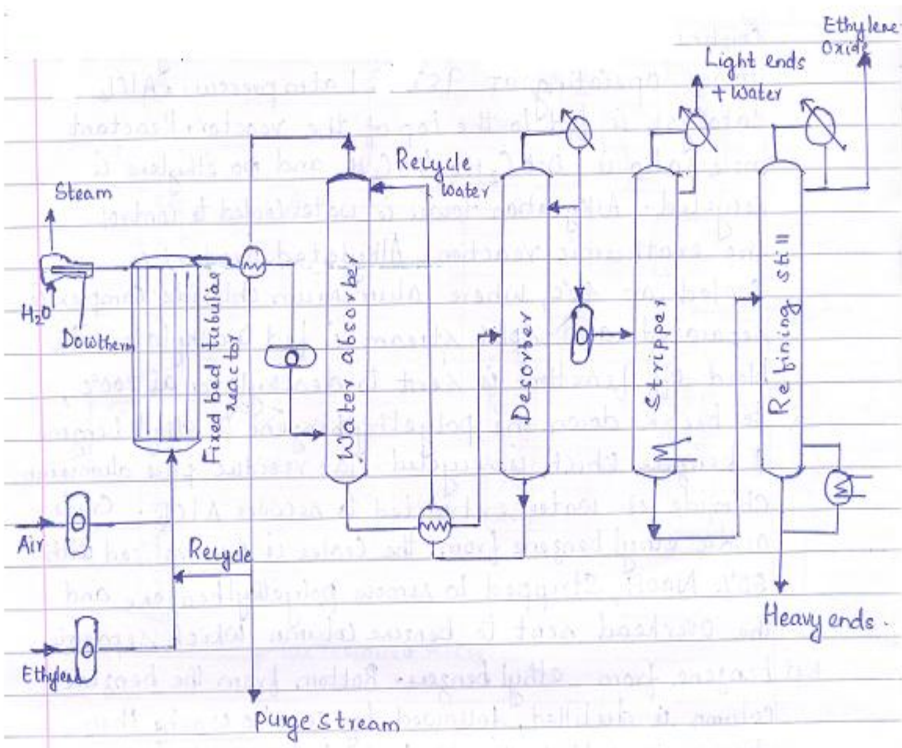


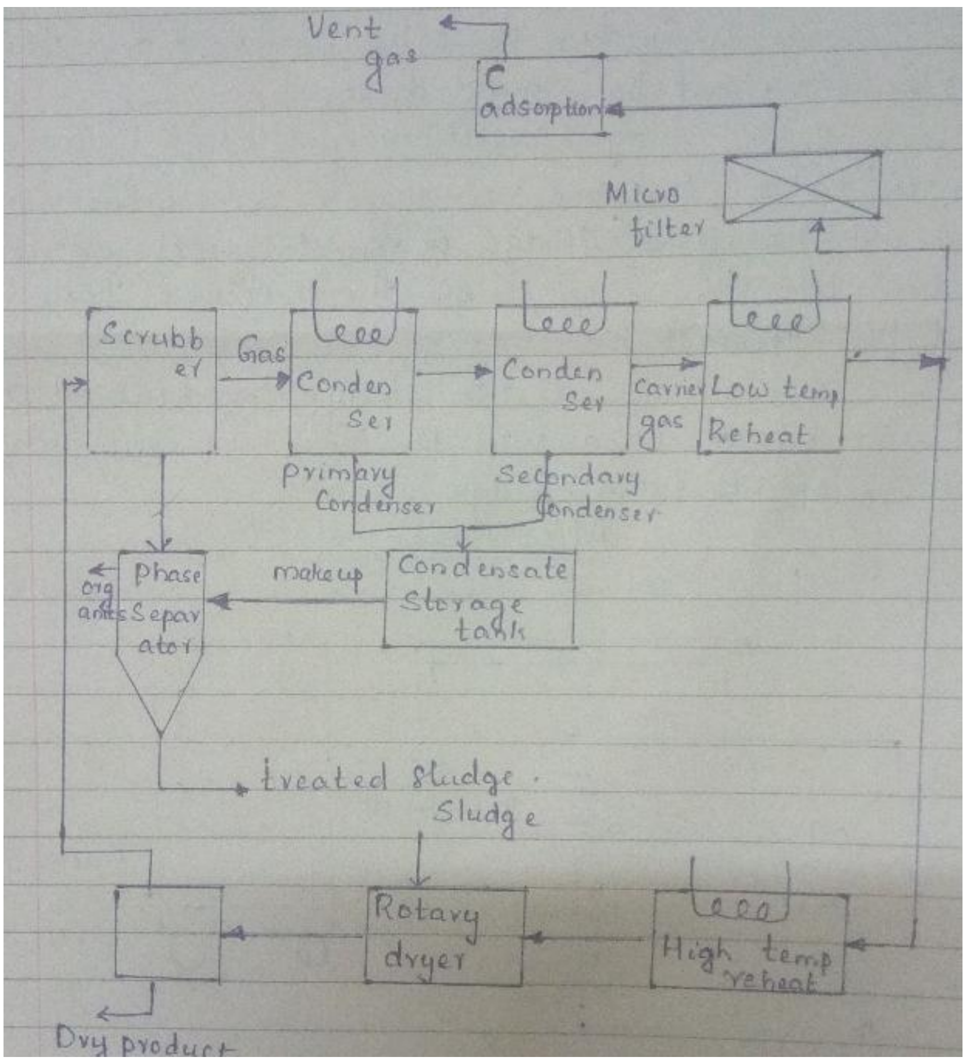
(c) Isomerization



(d) Hydrocracking

$$\underset{n\text{-heptane}}{CH_3(CH_2)_5CH_3} + H_2 \rightarrow \underset{\text{propane}}{C_3H_8} + \underset{\text{butane}}{C_4H_{10}};$$

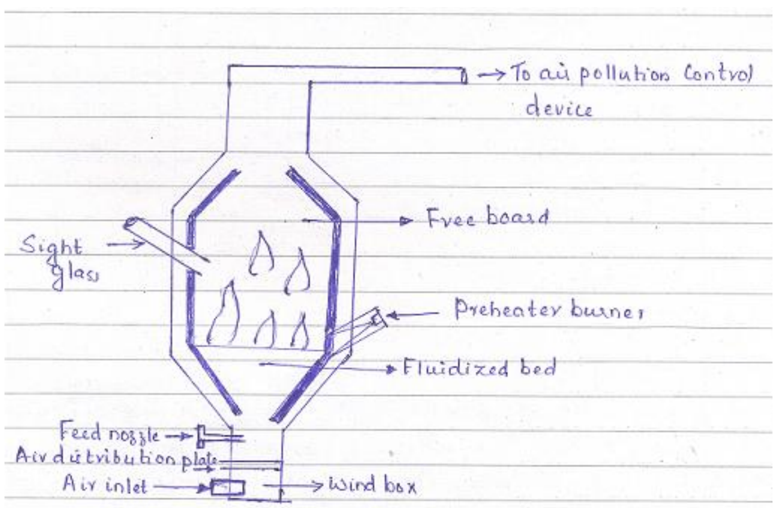
2	e	**Manufacture of ethylene oxide:** 	4
3		**Attempt any TWO of the following**	**16**
3	a	**Hazardous waste treatment:** **Low temperature thermal treatment process:** At low temperature of 250-450^oC, hazardous waste like polychlorinated biphenyls (PCB) are removed. The process uses an indirectly heated rotary drier to volatilize water and organic compounds in a sealed system. Hot treated solids are cooled and wetted to reduce dust formation. An inert gas carrier (N_2) transports the volatilized compound to a gas treatment train which removes entrained solid	

		particles with a scrubber and cools entire gas to less than 5^oC to condense organic compound. These can be recycled or disposed. The carrier gas is reheated to 315^oC and recycled to the drier. Very small quantities of the carrier gas are passed through a micro filter and a carbon adsorption system before discharging to atmosphere.  *(Any other method of hazardous waste treatment should be given due*	4

consideration.)

Solid waste treatment/disposal

Once the oil, hazardous organic and inorganic materials are removed from the concentrated sludge, it needs to be disposed off. Incineration is the combustion of material in the presence of stoichiometric quantity of air. Products of incineration are CO_2, H_2O and ash. Fluidized bed incinerator has a vertical cylinder refractory lined carbon steel vessel with a wind box for receiving the fluidizing air, air distributor plate for transmitting air to fluidize the bed, fluid bed of inert material into which the fuel or feed is injected and free board area. Suspended solid /gas mixture has vigorous boiling action and an extremely large heat transfer area, for combustion. Combustion is completed in free board area. Large solids get disengaged and fall back. 4



(Any other method of hazardous waste treatment should be given due consideration.)

3	b	**Fractions obtained from crude oil with their uses and boiling point range**	1 mark each

Fractions	**Boiling point range**	**Uses**
1. Uncondensed gases	< 30^{o}C	Domestic fuel, synthesis of organic chemicals.
2. Petroleum ether	30-70^{o}C	Solvent for fats, essential oils, used in dry cleaning.
3.Gasoline or petrol or motor spirit	40-120^{o}C	As a motor fuel for IC engines, solvent, in dry cleaning.
4. Naphtha	120-180^{o}C	As a solvent and in dry cleaning, feed stock for petrochemicals.
5. Kerosene oil	180-250^{o}C	Illuminant, fuel for stoves
6. Diesel oil	250-320^{o}C	Diesel engine fuels,

				carbureting of water gas	
		7.Heavy oil On vacuum distillation of heavy oil gives lubricating oil, petroleum jelly, greases, paraffin wax etc.	320-400^{o}C	Fuel for ships, metallurgical furnaces, feed stock for cracking processes.	
		8.Residue	> 400^{o}C	Used for making roads and water proofing roof, as a fuel, for moulding electrode rods.	

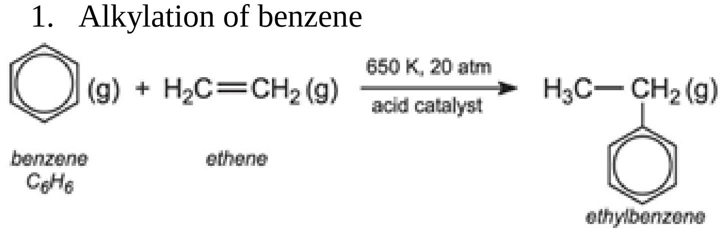
3 c

Manufacturing of styrene:

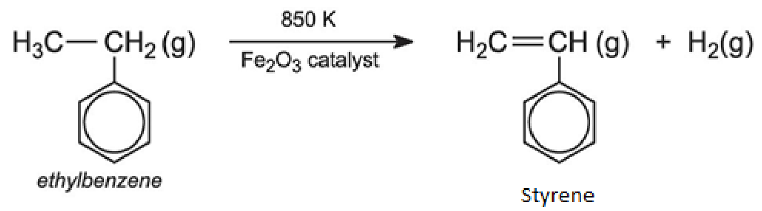
Description

Reaction involved in the manufacture of styrene:

1. Alkylation of benzene



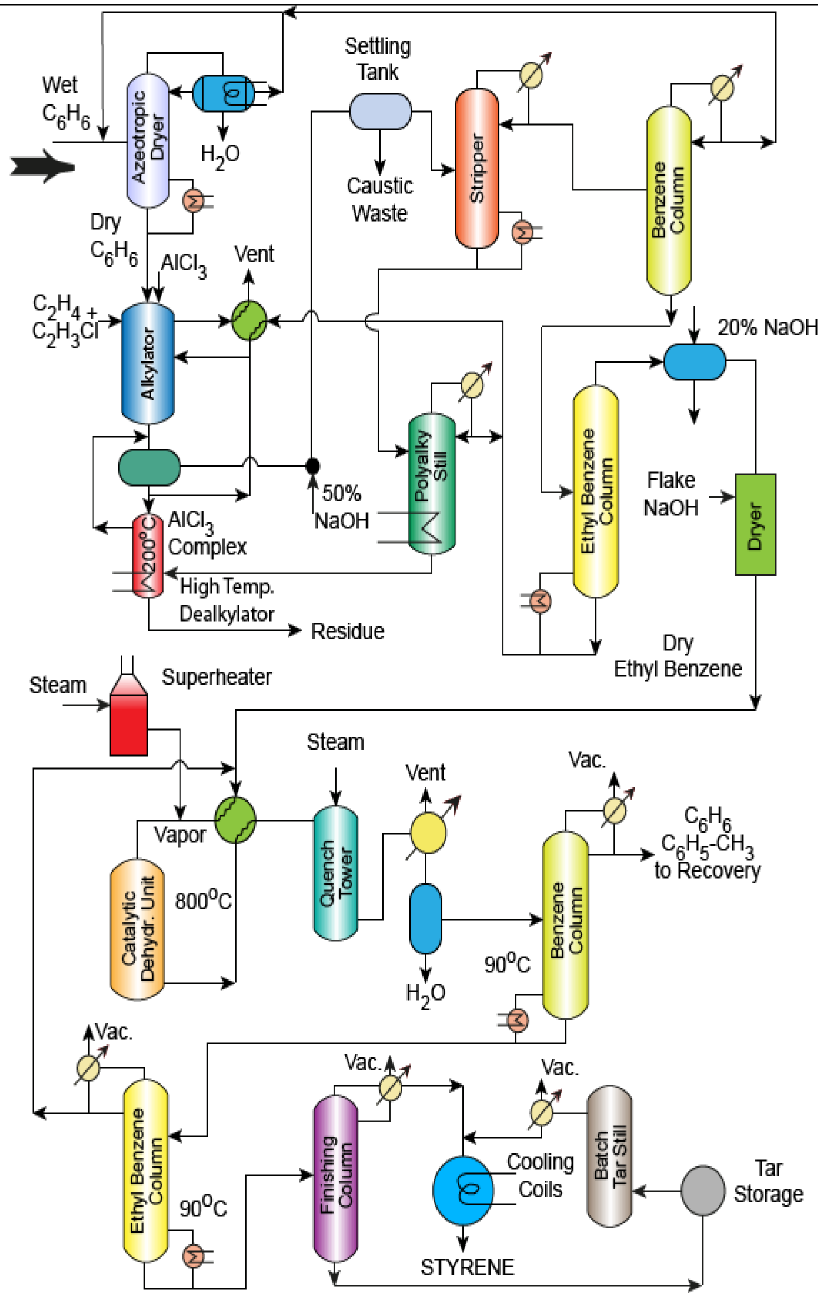
2. Dehydrogenation of ethyl benzene



Benzene is alkylated with ethylene using aluminum chloride or acid type catalyst. The resulting ethyl benzene is catalytically dehydrogenated in steam or excess benzene atmosphere to give styrene. Benzene feed must be dried by azeotropic distillation. Ethyl chloride is added to ethylene which is fed continuously with benzene to the alkylation tower operated at 95^0C & 1 atm. Crude acidic ethyl benzene from the cooler is neutralised with 50% NaOH, striped to remove polyethyl benzene & the overhead sent to benzene column which separates wet benzene from ethyl benzene. Dehydrogenation of ethyl benzene is the step which produces styrene. The mixed feed passes through the preheater to achieve an input temp. Of 500^0C.The dehydrogenation catalyst is promoted Zinc, chromium, iron. Reaction product is cooled in the feed preheater , then by steam quenching. Hydrocarbon mixture is passed into a series of vacuum distillation column to allow the separation of impurities at low temp to avoid polymerization of styrene. The second column at 35mm & 90^0c reboiler temperature separate styrene from ethyl benzene.

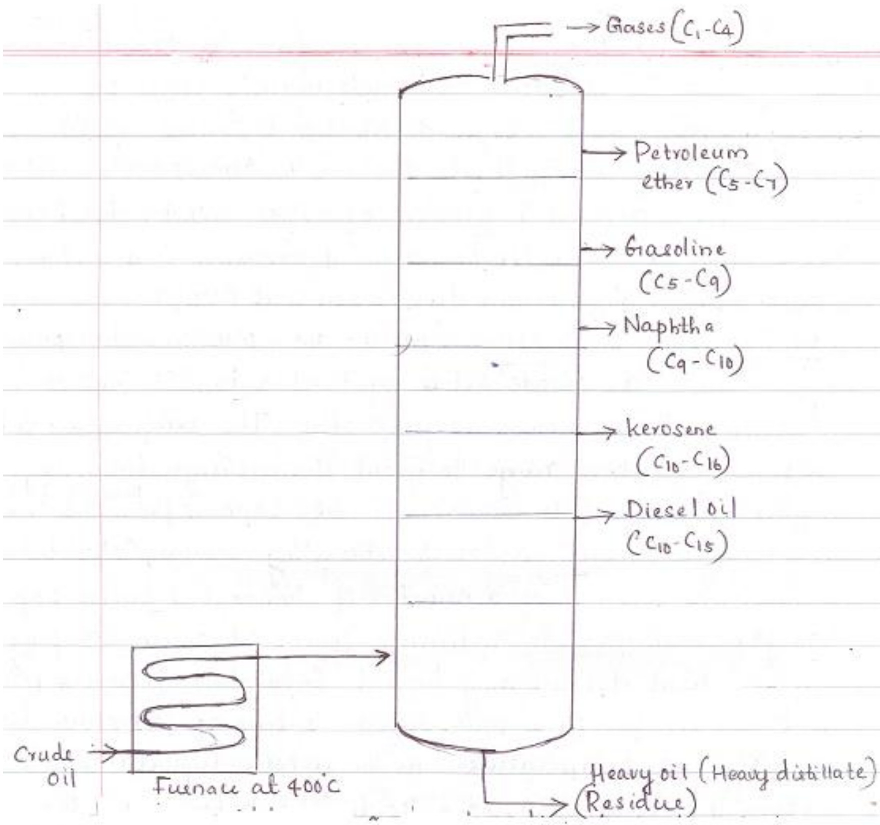
4

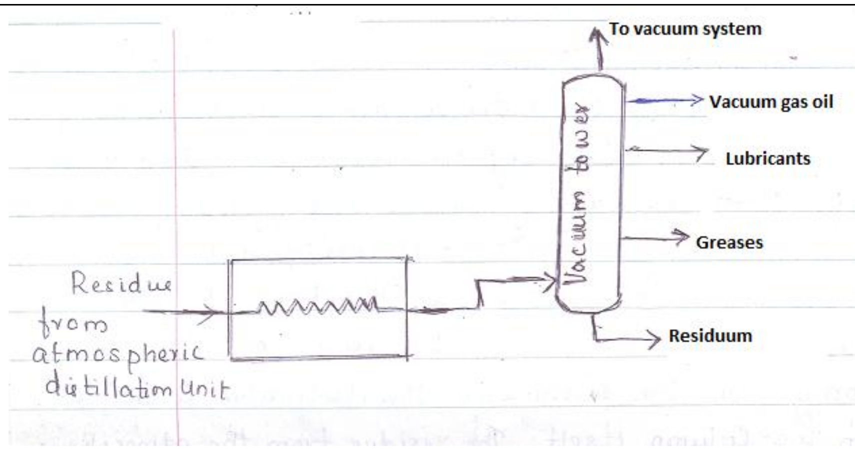
Flowsheet

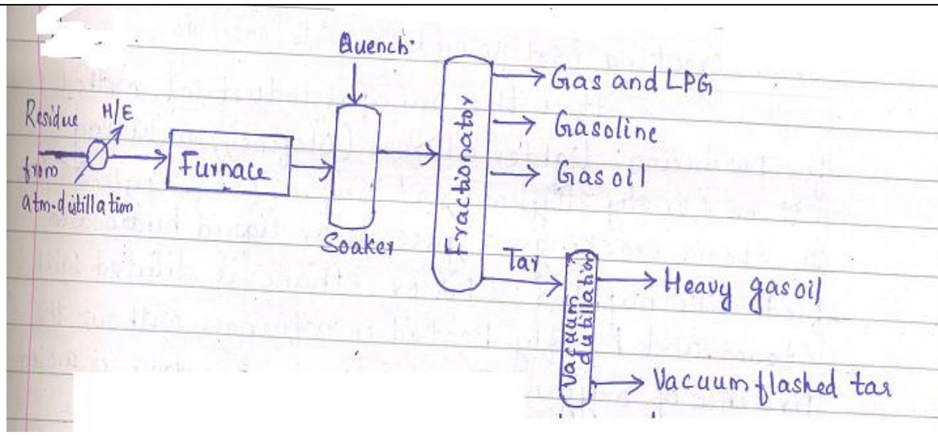
			4
4 a		**Attempt any THREE of the following**	**12**
4a	i	**OPEC** is Organization of Petroleum Exporting Countries.	1

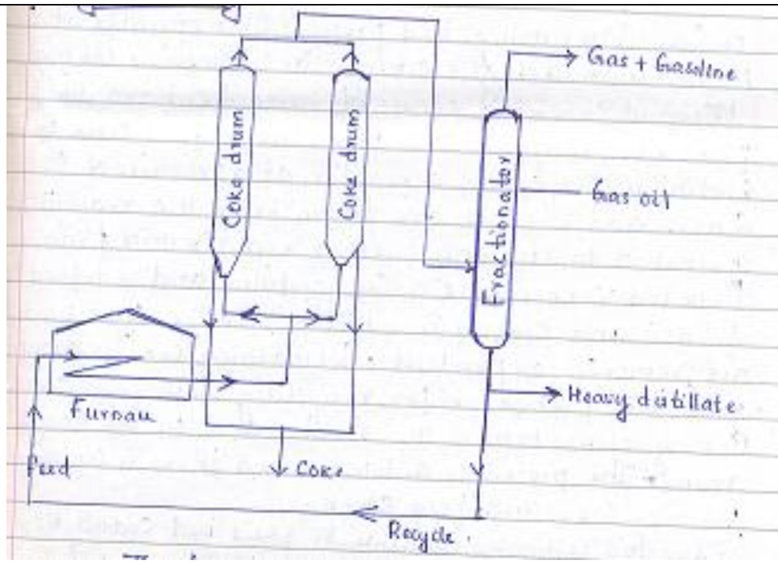
		Explanation: 43% of world crude produced is shared among the group members. Currently the organization has a total of 14 member countries. The member countries are Algeria, Angola, Congo, Ecuador, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, UAE, Venezuela Objectives of OPEC are 1. To avoid useless fluctuation in prices in international market. 2. To provide an efficient economic and regular supply of petroleum to consuming nations and a fair return of capital to those investing in petroleum industries	3
4a	ii	**Characteristics of crude oil:** 1.Crude is an yellowish black oily complex mixture 2. Flash point: below 10^0C 3. Kinematic viscosity: above 9.5 cSt 4. Pour point; 21^0C 5. Density: 0.83-0.9 gm/ml 6. API gravity:41 7. Specific heat: Lighter fractions have higher value 8. Heat of combustion: value decreases from paraffin to aromatics. 9. Viscosity index: Paraffinic base oils have high viscosity index and naphthenic base oils have low viscosity index. 10. Paraffin has less ignition temperature and aromatics have high ignition temperature. **Constituents of crude oil:** Crude oil is made up of the following elements 1. carbon-84% 2. hydrogen -14%	½ mark each for any 4 points

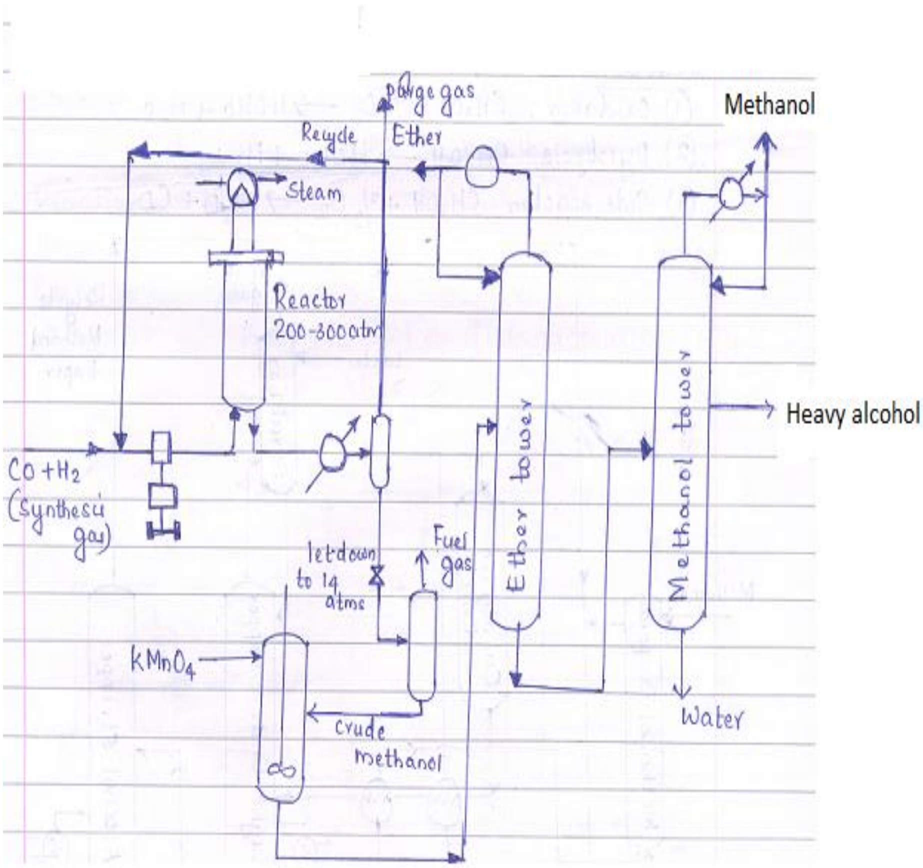
		3. sulphur-1-3% 4. nitrogen, oxygen, metals, salts- <1% The major compounds present in crude oil are: A. hydrocarbon i) Paraffins ii) Aromatics iii) Napthenes iv) dienes B. Non hydrocarbon i) S compounds ii)O_2 compounds iii)N_2 compounds C. Metallic compounds.	2
4a	iii	**Fractional distillation in refining process** **Atmospheric distillation process:** The crude oil is preheated to 350-380^oC in tubular furnace known as pipe still. Hot vapours plus liquid are passed through a tall fractionating column, called bubble tower. It consists of a number of bubble cap trays which provide intimate contact between escaping vapours and down coming liquid. Heavier hydrocarbons condense more quickly and settle in lower trays and lighter hydrocarbons remain as vapour for a long time and condense on higher trays. Light gases like methane, ethane etc pass out from the top of the column, petrol are formed in the top trays, kerosene and gas oils in the middle and fuel oils at the bottom. Residue drawn from the bottom is send to a vacuum distillation unit or burned as a fuel or used as a feed stock for cracking units.	2

		 **Vacuum Distillation:** The residue from the atmospheric distillation column is send to vacuum distillation unit where absolute pressure is maintained at 10 to 40mm of Hg using multiple stages of steam jet ejectors. Vacuum tower may produce gas oils, lubricating-oil base stocks, and heavy residues.	2

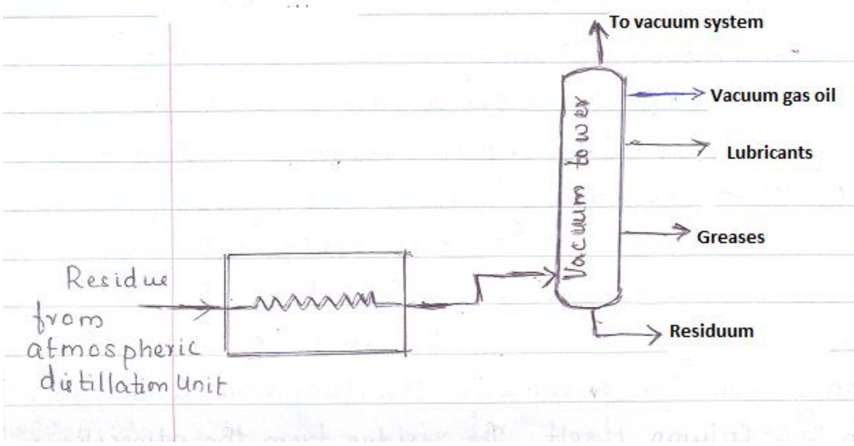
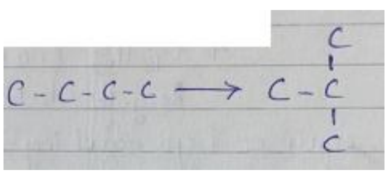
			
4a	iv	**Visbreaking:** **Description:** It is a mild form of thermal cracking which cracks large hydrocarbon molecules in the oil by heating in a furnace to reduce its viscosity and to produce small quantities of light hydrocarbons. Residue from the atmospheric distillation tower is heated in a heat exchanger to 250^{o}C and then heated to 425-510^{0}c at atmospheric pressure and mildly cracked in a heater. It is then quenched with cool gas oil to control over cracking and flashed in a distillation tower. The thermally cracked residue tar which accumulates at the bottom of the tower is vacuum flashed in a stripper and the distillate recycled.	2

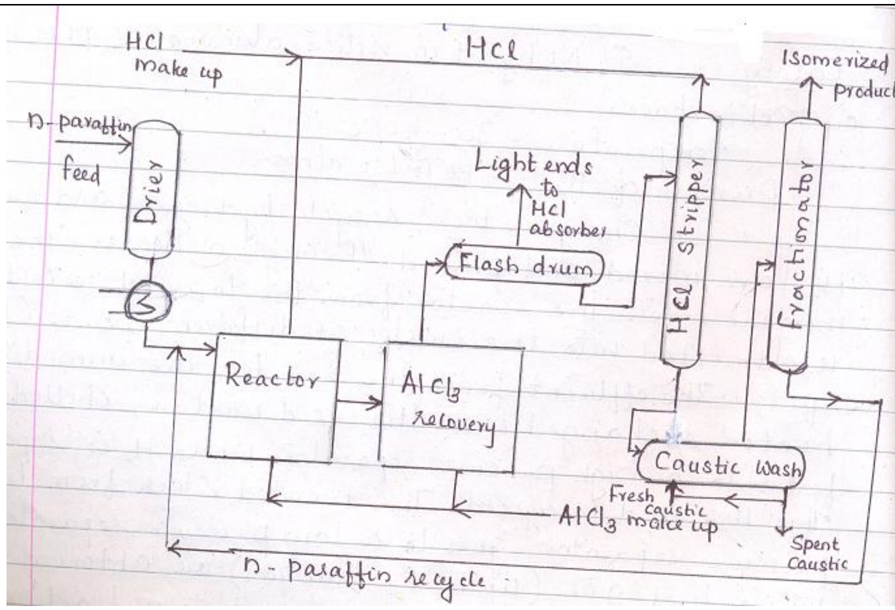
			2
4b		**Attempt any ONE of the following**	**06**
4b	i	**Delayed coking:** Initially the heavy feedstock (residue from atmospheric distillation unit) is fed to a furnace which heats it to high temperature (480-510^{o}c) at low pressures (25-30 psi) and is designed & controlled to prevent premature coking in the heater tubes. The hot mixture is passed from the heater to one or more coker drums where it is held for approximately 24 hours until it cracks into lighter products. Vapours from the drums are returned to fractionators, where gas, naphtha etc are separated out. After the coke reaches predetermined level in one drum, the flow is diverted to another drum to maintain continuous operation. Full drum is steam stripped to remove uncracked hydrocarbons, cooled by water injection and decoked by mechanical or hydraulic methods.	3

			3
4b	ii	**Methanol :** **Explanation:** Hydrogen and carbon monoxide in the mole ratio of 2.25 is compressed to 200-300 atm, mixed with recycle gas and fed to a high pressure converter. Internal preheating is done to maintain the temperature of 300-375^{0}C. Reactor is copper lined steel vessel and contains mixed catalyst of Zn, Cr, Mn Or Al oxides. Exit gases are cooled by heat exchange with reactants, then with water. The methanol condenses under full operating pressure to maximize yield. Liquid methanol is depressurized, purified by potassium permanganate to remove traces of ketones, aldehydes and other impurities, sent to a stripper to remove light ends such as dimethyl ether and to fractionators to separate methanol from high molecular weight compounds.	3

		Flowsheet  	3
5		**Attempt any FOUR of the following**	**16**
5	a	**Strength of Indian Petrochemical industry are** 1. Technically sound man power. 2. All types of transportations are available. 3. Huge demand 4. Atmospheric conditions are good. 5. Consolidation of the Indian Petrochemical industry in the last few years. 6. Most of the petrochemical players have integrated facilities, thereby	½ mark each for any 4 points

		reducing external dependence to a large extent. Further, petrochemicals business being a high value add, would add further to the profitability of these integrated companies. **Weakness of Indian Petrochemical industry are** 1. Crude oil production is less. 2. Depending on Middle East countries 3. Incompetency of rupees with dollar. 4. Low bargaining power vis-a-vis the suppliers**:** Input costs form nearly 50% to 60% of the raw material costs. 5. Low Bargaining power vis-a-vis customers**:** In case of increase in input costs, the companies might not be able to pass on the rise to the consumers as the prices of products is highly influenced by factors such as international prices and supply.	½ mark each for any 4 points .
5	b	**Vacuum distillation:** Heavier fractions from atmospheric distillation unit that cannot be distilled without cracking under its pressure & temperature conditions are vacuum distilled. Vacuum distillation is simply distillation of petroleum fractions at very low pressure to increase volatilization & separation. In most system vacuum inside the fractionators is maintained with steam ejector & vacuum pumps, barometric condensers or surface condensers. The injection of superheated steam at the base of vacuum fractionators further reduces the partial pressure of hydrocarbons in the tower, facilitating vaporization & separation.	4

			
5	c	**Isomerization process:** **Explanation:** Isomerization is used to convert normal paraffins to isoparaffins Catalyst: Aluminiumtrichloride, HCl is the promoter. Temperature: 100-150^{0}C. Pressure: 17-27 atms  Feed stock (n-paraffins) is dried, preheated and fed to a reactor where efficient contact between reactants and catalysts takes place. HCl and make up $AlCl_3$ are also added. $AlCl_3$ recovery by condensation or distillation is necessary because it is volatile in reactor conditions and slightly soluble in liquid hydrocarbons. Removal of light ends by flashing, followed by HClstripping , caustic wash and fractionation are the standard procedures performed to produce isomerized gasoline. **Flow sheet**	2

		 ***(Any other type of isomerization process should be given due consideration)***	2
5	d	**Alkylation:** Alkylation process in petroleum refining combines low molecular weight olefins with paraffinic hydrocarbon in the presence of catalyst. The product is called alkylate. C_4H_8 + i C_4H_{10} $\rightarrow$ 2,2,4 trimethyl pentane Alkylation, in petroleum refining is a chemical process in which light, gaseous hydrocarbons are combined to produce high-octane components of gasoline. The light hydrocarbons consist of olefins such as propylene and butylene and isoparaffins such as isobutane. These compounds are fed into a reactor, where, under the influence of a sulfuric-acid or hydrofluoric-acid catalyst, they combine to form a mixture of heavier hydrocarbons. The liquid fraction of this mixture, known as alkylate, consists mainly of isooctane, a compound that	2

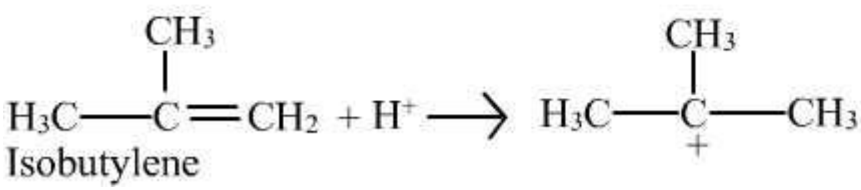
lends excellent antiknock characteristics to gasolines.

Eg is sulphuric acid alkylation process,

Reaction involved

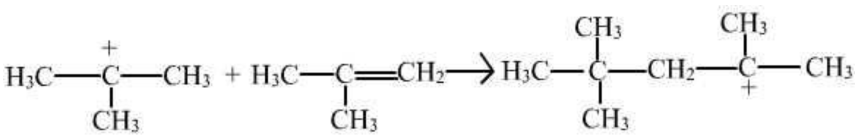
STEP 1: Addition of proton H^+(supplied by Acid catalyst to propagate double bond of olefin)

Carbonium ion Formation



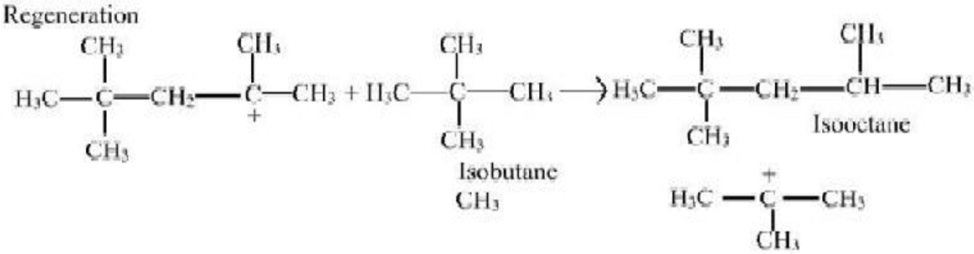
STEP 2**:** Addition of this ion to another olefin

2



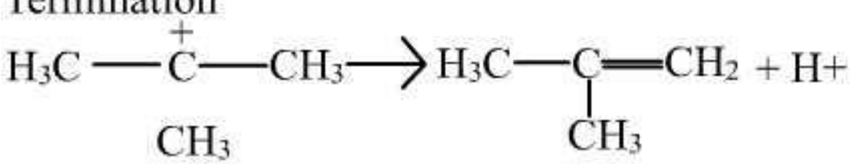
STEP 3: Abstraction of Hydride ion H- from olefin.

Regeneration

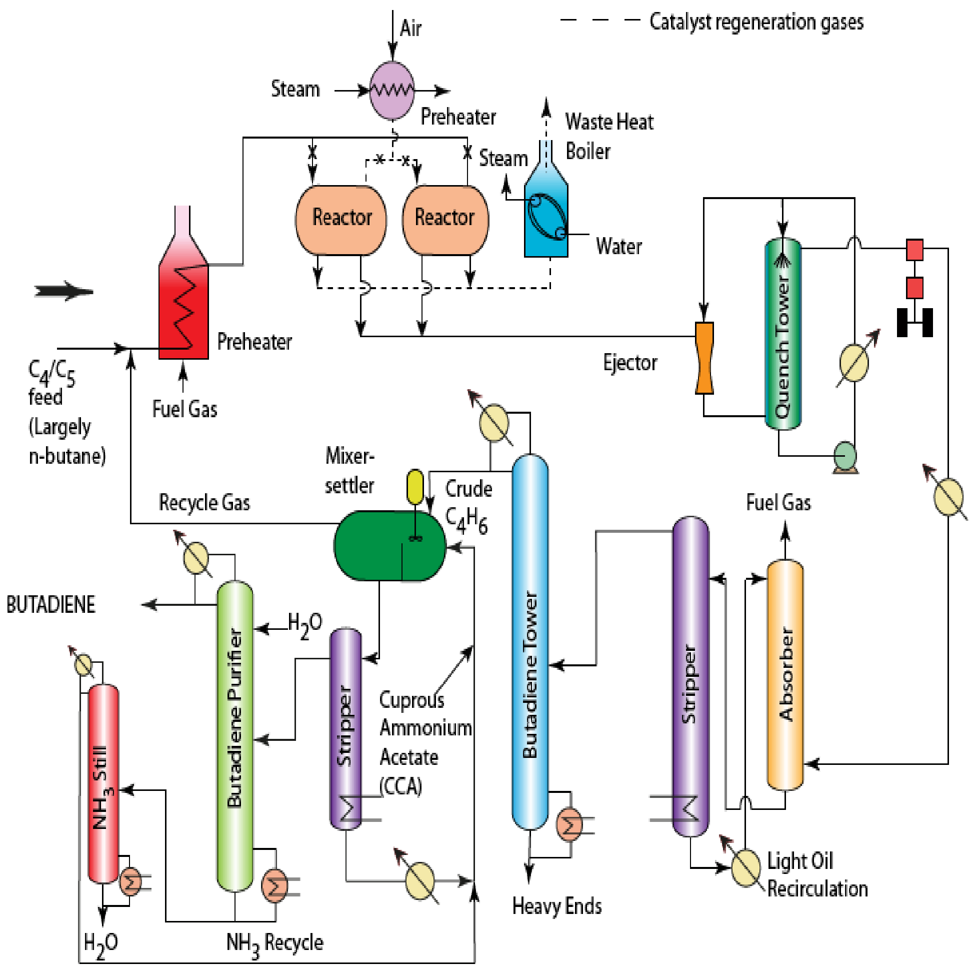


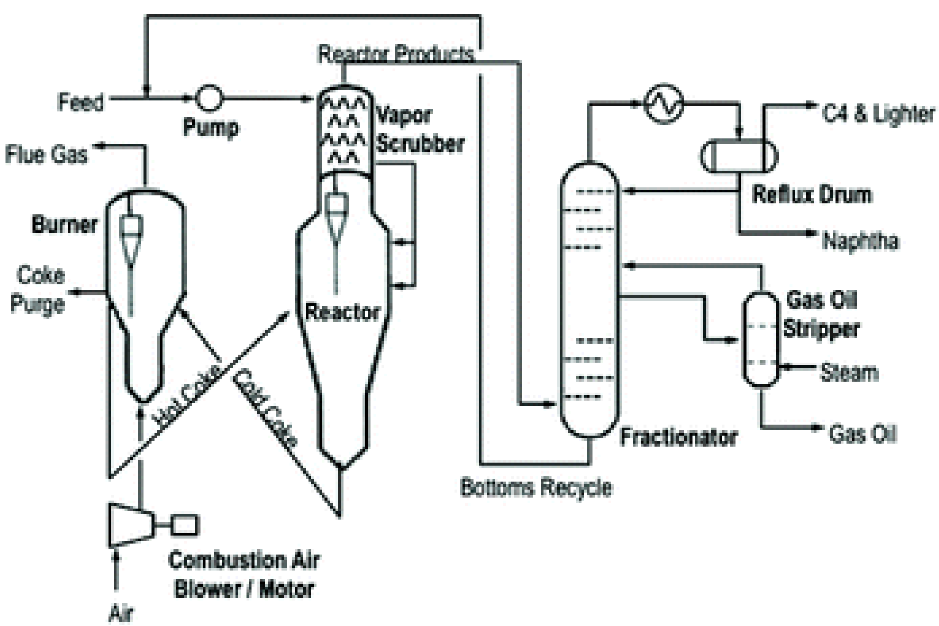
Step 4

Termination

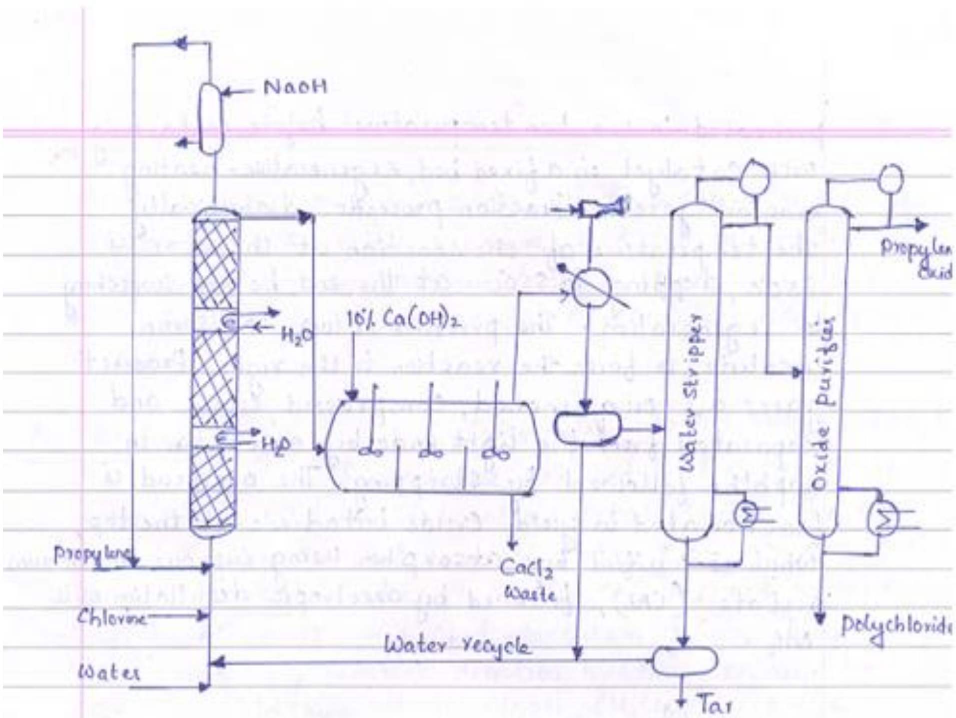


		$i-C_4H_{10} + C_3H_6 \longrightarrow i-C_7H_{16}$ $i-C_4H_{10} + C_4H_8 \longrightarrow i-C_8H_{18}$ $C_3H_6 + C_6H_6 \longrightarrow$ Isopropyl benzene $C_2H_4 + C_6H_6 \longrightarrow$ Ethyl benzene Petrochemicals	
5	e	**Definitions:** **Cetane number:** It is defined as the percentage volume of n-cetane in a mixture of n-cetane and heptamethylnonane that gives the same ignition delay as the fuel under consideration. **Ignition temperature:** The lowest temperature at which a material can catch fire and burn continuously without the aid of external firing agencies.	2 2
6		**Attempt any TWO of the following**	**16**
6	a	**Manufacture of butadiene:** **Reaction:** Main reaction-$C_4H_{10} \rightarrow CH_2=CH.CH=CH_2+2H_2$ Side reaction-$C_4H_{10} \rightarrow C_4H_8+H_2$ **Explanation:** A refinery gas of C4/C5 containing n-butane with some isopentane is mixed with recycle gas & preheated to reaction temperature .prior to contact with catalyst in a fixed bed, regenerative heating reactor system. The temperature of reaction at start of make period is 650^0C, dropping to 550^0C at the end before switching to regeneration. The pressure is low 120-150mm absolute, to force reaction to right.The product gases are oil quenched, compressed, cooled& separated from the light ends by absorption in naphtha followed by stripping.	2 2

		The overhead is fractionated to yield crude butadiene at the top which is purified by absorption using cuprous ammonium acetate, extractive distillation with furfural or azeotropic distillation with ammonia. **Flow sheet** 	4
6	b	**Coking Process:** **Coking** is a refinery unit operation that upgrades material called bottoms from the atmospheric or vacuum distillation column into higher-value products and produces petroleum coke by the application of heat and pressure. Feed stocks	2

		not suitable for ordinary thermal or catalytic cracking are usually fed to coking units.	
		Types of coking:	
		The 3 types of coking are delayed coking, continuous coking and fluid bed coking.	2
		Continuous coking: continuous coking is a moving bed process that operates at temp higher than delayed coking.In continuous coking thermal cracking occurs by using heat transferred from hot, recycle coke particles to feedstock in a radial mixer,called a reactor. Gases&vapours are taken from the reactor, quenched to stop any further reaction &fractionated.Coking occurs both in the reactor & the surge drum.The process is automatic in that there is a continuous flow of coke & feedstock.	2
			2
		(Any other type of coking should be given due consideration)	

6	c	**Propylene oxide:** **Reaction**: It is produced via chlorohydrin route. 1. Chlorhydrination : $CH_3CH{=}CH_2 + HOCl \rightarrow CH_3\text{-}CHCl\text{-}CH_2OH$ 2. Dehydrochlorination: $2CH_3\text{-}CHCl\text{-}CH_2OH + Ca(OH)_2 \rightarrow CH_3CHCH_2O + CaCl_2 + 2H_2O$	2
		Description: Propylene, chlorine & water are introduced into the bottom of a packed tower where chlorohydrin is formed. The reaction mechanism is formation of hypochlorous acid which reacts rapidly with propylene. Reaction is exothermic and maximum tower temperature is held at 50^0C by admitting cold water. Unreacted propylene is scrubbed with NaOH to remove HCl. The liquid stream containing chlorohydrin is drawn and neutralized with lime. Then it is steam stripped to remove propylene oxide in to the overhead condenser. The condensate is a mixture of oxide, water and small amount of propylene dichloride and other organics. Then it is fractionated to separate propylene oxide. **Flowsheet**	2

			2
		Uses (any two) In the manufacture of propylene glycol, glycerin, glycol ether, isopropanol amines, propylene carbonate, it can be used as a component for a variety of surfactants for gas dispersion, detergency and friction reduction, it can be reacted with phosphorous derivatives to create flame retardants, They can be used in polyurethane foams, textiles and floorings. Modified carbohydrates or starches can be used in a variety of applications in the construction, paint, food and pharmaceutical industries.	2