Time 3 Hrs   **Marks 80**

(1)   Question No. 1 is compulsory.

(2)   Attempt any three questions out of remaining five questions.

(3)   **Figures** to the right indicate full marks.

(4)   **Assume suitable data wherever necessary.**

Q.1 Solve any four	
a) What are the primary responsibilities of process engineer in the process industries?	**05**
b) Explain process integration activities	**05**
c) What are the various mass integration strategies for attaining targets.	**05**
d) What are the optimum stream rerouting strategies?	**05**
e) Explain hierarchy of mass integration strategies.	**05**
Q2 Vinyl acetate monomer manufacturing process is given in Fig. Solve by algebraic method to find out minimum discharge. Draw LID and Cascade Diagram revised.	**20**

Source Data

	Flow Rate Kg/h	Inlet Mass fraction
Bottom of Absorber II	1400	0.14
Bottom of Primary Tower	9100	0.25

Sink Data

	Flow Rate Kg/h	Max. Mass Conc
Absorber I	5100	0.05
Acid Tower	10200	0.01
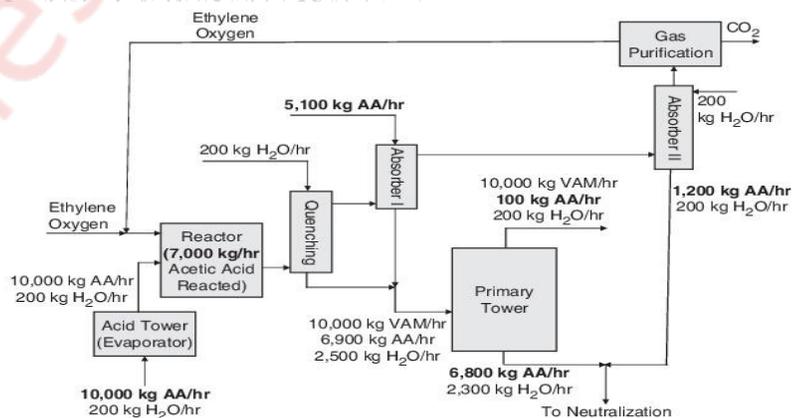
Q3   Benzene is to be removed from a gaseous emission by contacting it with an absorbent (wash   **20**
oil, molecular weight 300). The gas flow rate is 0.2 kg-mole/s (about 7700 ft^3/min) and it
contains 0.1% mol/mol (1000 ppm)of benzene. The molecular weight of the gas is 29, its
temperature is 300K,and it has a pressure of 141 kPa (approximately 1.4 atm). It is desired to

Page **1** of **6**

59833

reduce the benzene content in the gas to 0.01% mol/mol Benzene is first absorbed into oil. The oil is then fed to a regeneration system in which oil is heated and passed to a flash column that recovers benzene as a top product. The bottom product is the regenerated oil, which contains 0.08 % mol/mol benzene. The regenerated oil is cooled and pumped back to the absorber. What is the optimal flowrate of recirculation oil that minimizes the TAC of the system?

Data

1) Assume Raoults law

2)Vapor pressure of benzene 14.101 Pa

Absorber Sizing Criteria

The overall-gas height of transfer unit for the packing is 0.58 m.

The superficial velocity of the gas in the absorber is taken as 1.5 m/s to avoid flooding.

The mass velocity of oil in the absorber should be kept above2.7 kg/m^2 s to insure proper wetting.

Cost Information

The operating cost (including pumping, oil makeup, heating, and

cooling) is Rs.40/kg-mole of recirculating oil.

The system is to be operated for 325days/annum. The installed cost of the absorption column (including auxiliaries, but excluding packing) is given by

Installed cost of column $=2290 \ H^{0.85} D^{0.95}$

where H is the packing height (m) and D is the column diameter (m).

The packing cost is Rs 47500/m^3

The oil-regeneration system is to be salvaged from a closing unit in the plant. Hence, its fixed cost will not be accounted for in the optimization calculations.

The absorber and packing are assumed to depreciate linearly over five years with negligible salvage values.

59833
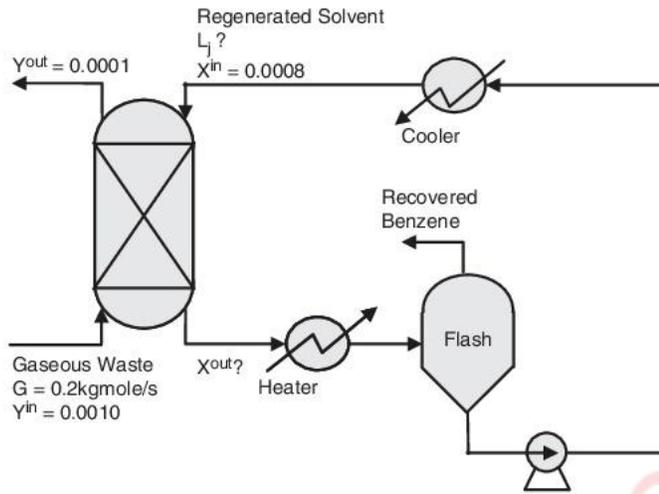
Q4   In a metal degreasing process presented in Figure Currently, a fresh organic solvent is used in   **20**
the degreaser and the absorber. A reactive thermal processing and solvent regeneration system
is used to decompose the grease and the organic additives, and regenerate the solvent from the
degreaser. The liquid product of the solvent regeneration system is reused in the degreaser,
while the gaseous product is passed through a condenser, an absorber, and a flare. The process
produces two condensate streams: Condensate I from the solvent regeneration unit and
Condensate II from the degreaser. The two streams are currently sent to hazardous waste
disposal. Since these two streams possess many desirable properties that enable their possible
use in the process, it is recommended that their recycle/reuse to be considered. The absorber
and the degreaser are the two process sinks. The two process sources satisfy many properties
required for the feed of the two sinks. An additional property should be examined; namely
Reid Vapor Pressure (RVP), which is important in characterizing the volatility, makeup, and
regeneration of the solvent.

Property of Loads

Sink	Flow rate (Kg/S)	Upper bound RVP(atm)	Upper bound RVP $^{1.44}$	Max. Property Load
Degreaser	5.0	3.0	4.87	24.35
Absorber	2.0	4.0	7.36	14.72

The mixing rule for vapor pressure (RVP) is given by the following expression:

$$RVP^{1.44} = \sum x_i RVP_i^{1.44}$$

The RVP for condensate I is a function of the thermal regeneration temp as follows

$$RVP_{CondensateI} = 0.5 e^{[(T-100)/175]}.$$

59833

Properties of Process sources and Fresh

| Source	Flowrate (Kg/s)	RVP(atm)
Process condensate I	4.0	6.0
Process Condensate II	3.0	2.5
Fresh Solvent	To be determined	2.0

a)What is the target for minimum fresh usage when direct recycle is used?

b) Of the process is to be modified by manipulating the temp. of the condenser , what is the target for min fresh usage?
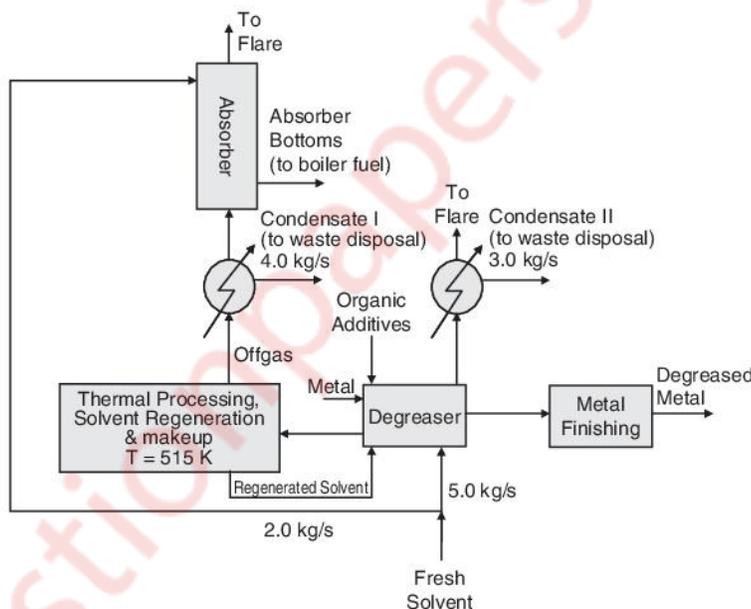
Q5   A schematic process flow sheet is given in Figure .Plastic waste (feedstock) is first shredded **20**
then sorted in a sink/flotation unit to remove polyvinyl chloride (PVC) and undesirable
feedstock. The suspension from the sink floatation unit is filtered. The refuse from filtration is
rejected and the filtrate is recycled to the sink flotation unit. The remaining feedstock is sorted
and dried using 50,000 kg/h of hot gas. At present, this hot gas contains no butane. Also, no
butane is formed in sorting and drying. The hot gas leaving the sorting and drying process is
passed through a cyclone to remove suspended solids as refuse. The cyclone is followed by a
flare where any organics are burned. The sorted/dried feedstock enters a depolymerization
unit where a butane-laden gaseous stream (total flow rate of gas is 60,000 kg/h and it contains
7200 ppm w% butane) is generated. The slurry leaving the depolymerization unit is upgraded
in a catalytic unit then separated into various hydrocarbon cuts. The off-gas leaving the
catalytic upgrading unit has a flowrate of 25,000 kg/h and contains 80,000 ppmw of butane.
The depolymerization unit is heated using a recirculating heating oil coming from a furnace.
The feed to the furnace consists of 30,000 kg/h of syngas (composed primarily of butane),
10,000 kg/h of butane, and 340,000 kg/h of air. The exhaust from the furnace contains almost
no butane. The gaseous streams from the depolymerization and catalytic units were mixed and
fed to a boiler/industrial furnace (BIF). Due to economic, safety, and environmental concerns

Page **4** of **6**

59833

the BIF operation is to be discontinued and the mixed off-gas is to be rerouted in the plant.

a. What is current flowrate (kg/h) of purchasd fresh butane?

b. What is the total amount (kg/h) of butane generated by chemical reaction in the process?

c. How much (kg/h) butane is depleted by chemical reaction in the process?.

d. What is the target (kg/h) for minimum purchase of fresh butane?
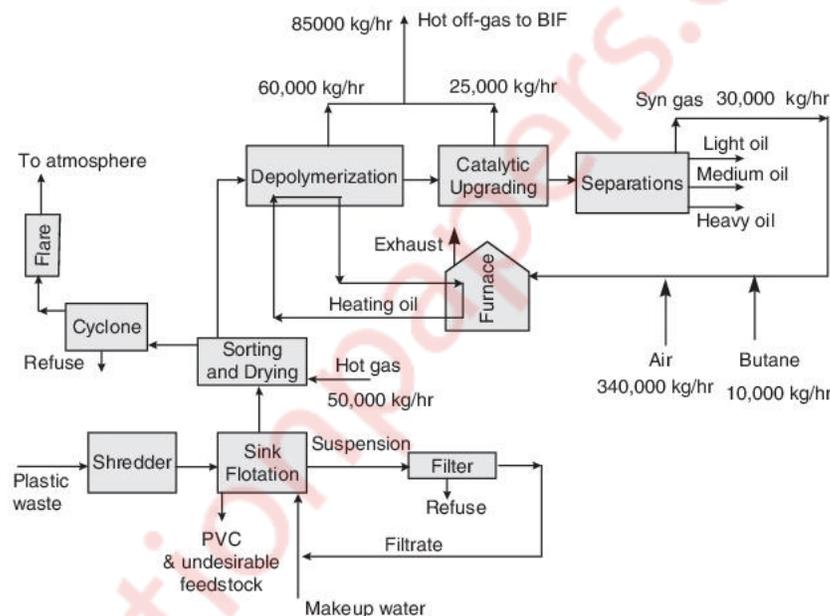
Q.6   In the magnetic tape manufacturing process, coating ingredients are dissolved in 0.09 kg/s of **20**
organic solvent and mixed to form a slurry. The slurry is suspended with resin binders and
special additives. Next, the coating slurry is deposited on a base film. Nitrogen gas is used to
induce evaporation rate of solvent that is proper for deposition. In the coating chamber, 0.011
kg/s of solvent are decomposed into other organic species. The decomposed organics are
separated from the exhaust gas in a membrane unit. The retentate stream leaving the
membrane unit has a flow rate of 3.0 kg/s and is primarily composed of nitrogen that is laden
with 1.9 wt/wt% of the organic solvent. The coated film is passed to a dryer where nitrogen
gas is employed to evaporate the remaining solvent. The exhaust gas leaving the dryer has a
flow rate of 5.5 kg/s and contains 0.4 wt/wt% solvent. The two exhaust gases are mixed and
disposed off. It is desired to undertake a direct-recycle initiative to use solvent-laden nitrogen
(gaseous wastes) in lieu of fresh nitrogen gas in the coating and drying chambers. The
following constraints on the gaseous feed to these two units should be observed:

Coating

59833

3.0 ≤flowrate of gaseous feed(Kg/s) ≤3.2

0.0 ≤wt% of solvent ≤0.2

Dryer

5.5 ≤ flowrate of gaseous feed (Kg/s) ≤6:0

0.0≤ wt % of solvent ≤0.1

It may be assumed that the outlet gas compositions from the coating and the dryer chambers are independent of the entering gas compositions.Using segregation, mixing and direct-recycle, what is the minimum consumption of nitrogen gas that should be used in the process? What are the strategies leading to the target?

59833

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