VORTEX 13.0

Sr. IDP

PROBLEM STATEMENTS 2026

PROBLEM A

AMINE STREAM TREATMENT

In one of our Production facility, we are generating a waste stream which is actually a diluted amine solution stream.

A typical analytical test report of this stream is as below.

Appearance = Clear yellow coloured Liquid (No suspended particle)

Moisture Content = 73%
Aliphatic diamine = 1.0%
Aromatic amine = 1.0%
Alicyclic amine (Molecular weight = 90-110 g/mol) = 6.0%
Aliphatic amine (Molecular weight < 50 g/mol) = 15%
A unknown Amine = 4%
COD = 147312 PPM
Total ammoniacal nitrogen (TAN) = 62838 PPM

We would appreciate if you can assist us in developing an efficient and economical treatment process for this stream.

As per the local regulatory bodies, the release/disposal specification for the treated stream is

(1) pH 6.0 -8.5
(2) BOD (3 days 27°C) < 30 mg/L
(3) COD < 250 PPM (mg/L)
(4) TSS < 100 mg/L
(5) Oil & Grease < 10 mg/L
(6) Sulphides as S < 2 mg/L
(7) Phenolic Compounds 1mg/L
(8) TAN < 50 PPM (mg/L)
(9) Chlorides < 600 mg/L
(10) Sulphates < 1000 mg/L
(11) Total Dissolved Solids < 2100 mg/L

However, our current challenge for this stream is to achieve the specified limit of COD and TAN values

PROBLEM B

SCALE UP OF TRICKLE BED REACTOR

Scale-Up of a Trickle Bed Reactor from Laboratory to Commercial Scale

A chemical manufacturing company has successfully developed a laboratory-scale Trickle Bed Reactor (TBR) for the hydrogenation of nitrobenzene to aniline using a palladium-on-carbon (Pd/C) catalyst. The laboratory reactor demonstrates stable operation with high conversion and selectivity under controlled operating conditions.

Laboratory-Scale Reactor Data

- Reactor type: Trickle Bed Reactor
- Catalyst: Pd/C
- Catalyst weight: 1 kg
- Feed rate: 5 kg/h (nitrobenzene)
- Operating temperature: 200 °C
- Operating pressure: 25 bar
- Hydrogen to nitrobenzene molar ratio: 4:1
- Conversion achieved: 98%

Production Requirement

Scale up the lab scale process to a commercial unit of 5000 TPA Aniline capacity

The design and analysis should address the following aspects:

1. Selection and justification of appropriate scale-up criteria such as space velocity, catalyst loading, and pressure drop.
2. Estimation of the total catalyst requirement for commercial-scale operation.
3. Reactor Sizing: Multitubar reactor with reactor internals
4. Identification of potential hydrodynamic, mass transfer, and heat transfer limitations that may arise during scale-up.
5. Recommendation of engineering and operational solutions/Guidelines to ensure safe, efficient, and reliable commercial reactor performance.

PROBLEM C

SLURRY FLOW REACTOR FOR MALEIC ANHYDRIDE

Design Problem: Slurry Flow Reactor for Maleic Anhydride Hydrogenation to Succinic Anhydride
Succinic anhydride is a key intermediate in the production of resins, plasticizers, and pharmaceuticals. Industrially, it is produced by hydrogenation of maleic anhydride using a slurry-phase reactor with a finely powdered Ni/Al_2O_3 or Pd/C catalyst suspended in a suitable solvent.This reaction is highly exothermic and requires efficient heat removal, good gas–liquid–solid contact, and proper catalyst handling.
Lab-Scale Data

- Reactor type: CSTR at lab scale
- Catalyst type: Ni/Al_2O_3 slurry
- Catalyst loading: 5 wt% of maleic anhydride
- Feed: Maleic anhydride in solvent
- Hydrogen feed: 3 mol H_2 per mol maleic anhydride
- Temperature: 200–220 °C
- Pressure: 25 bar
- Conversion observed: 96%

Selectivity observed: 98%
Industrial Production Requirement: Scale up the process to produce 5000 TPA of succinic anhydride while maintaining the same conversion, selectivity, and operational safety.Designing a
Slurry Flow Reactor for industrial-scale production of succinic anhydride. Address the following:

- Reactor Design: Justify the most suitable reactor type (e.g., tubular, multi-channel) for the slurry system.
- Sizing & Catalyst: Calculate reactor volume from lab data and estimate total catalyst loading for industrial scale.
- Thermal Control: Propose an effective cooling strategy to manage reaction heat and prevent hot spots.
- Hydrodynamics & Mass Transfer: Optimize gas–liquid–solid contact, prevent catalyst settling, and manage pressure drop.
- Scale-Up: Identify scaling challenges (mixing, heat, mass transfer) and propose engineering solutions for successful transition.
- Safety: Highlight critical safety hazards and propose mitigation strategies.
- Economics: Compare the Capital Expenditure (CAPEX) for a CSTR versus the proposed Flow Reactor design.