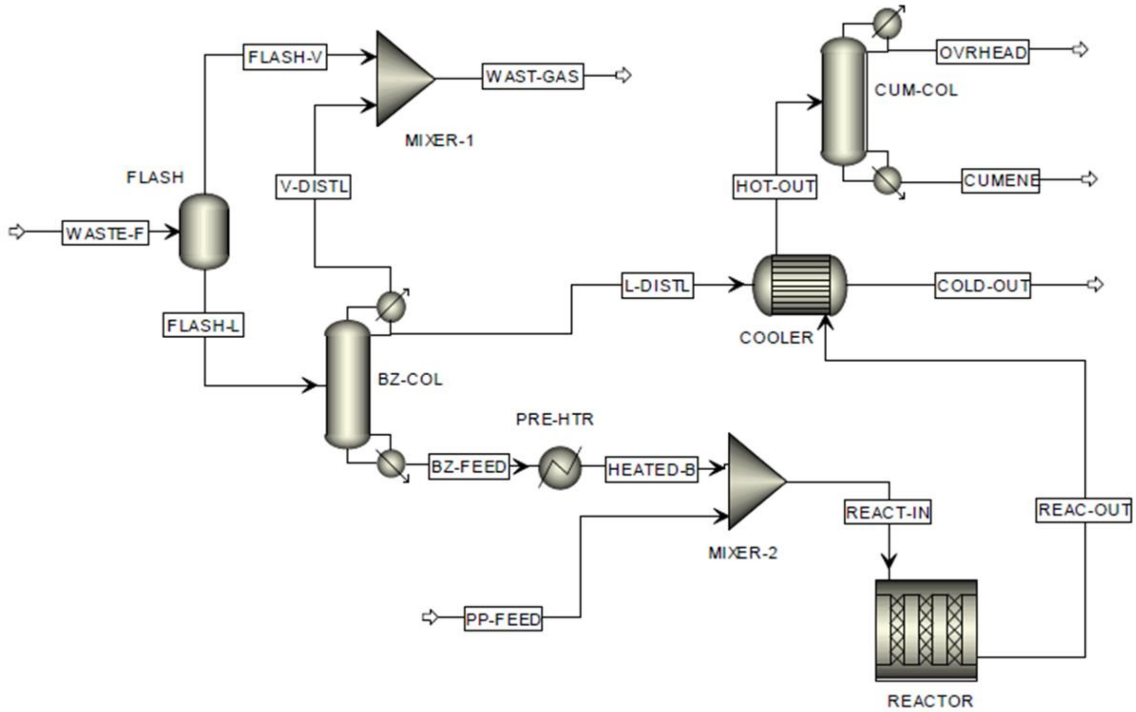
CH 4250: Process Engineering

Assignment 5

Name: ________________________________ Roll No: ___________________________

A wastewater stream with 50 mol% benzene is to be treated to remove impurities so it could be used to produce cumene (isopropyl benzene). The process flowsheet is shown below.



The wastewater first enters a flash to remove light gases. The liquid from the flash then enters a distillation column to separate out high-purity benzene in the bottom stream. After that, this liquid benzene is pre-heated to a super-heated state and combined with propylene (100% pure at 200 °F and 14.7 psia). Benzene and propylene are then allowed to react to form cumene in an isothermal plug flow reactor. The reactor effluent is cooled in a heat exchanger by the liquid distillate from the first column. A second distillation column is used to purify cumene which exits as the bottom product.

The following data is available for the process:

A. The temperature of the wastewater feed is 100 °F and its pressure is 20 psia. Its composition is: 60% benzene, 18% methanol, 12% methane, 6% acetylene (C2H2), 3% nitrogen, and 1% oxygen (all molar basis), and the total flow rate is 200 lbmol/hr.

B. The wastewater stream is flashed at 0 °F with negligible pressure drop.

C. The first column (BZ-COL) has 20 theoretical stages, which include a partial condenser (Pcondenser = 14 psia) and a reboiler (Preboiler = 15 psia). The feed tray location is 15. The column operates with a molar reflux ratio of 3 and takes out 90 lbmol/hr in the bottom stream.

D. The pre-heater vaporizes the benzene stream and superheats it to 30 °F above its dewpoint temperature. The pressure drop inside the pre-heater is 0.3 psia.

E. The waste gas stream (WAST-GAS) has a maximum total flow rate of 37.0 lbmol/hr. (Pollution Control Board rule)

F. The plug flow reactor has a diameter of 1.2 ft with negligible pressure drop. The kinetics for the cumene reaction is given as:

$$r_{propylene} = kC_{propylene}C_{benzene}$$

$$k = 1.5 \times 10^{4} \exp\left(\frac{-5500}{RT}\right)$$

where the unit of the activation energy is Btu/lbmol and C_i is molar concentration. The conversion of the cumene reaction is maintained at 99%.

G. The plug flow reactor is operated isothermally at the same temperature as that of the inlet to the reactor (REAC-IN).

H. The exit temperature of the cold side in the cooler is **90+Y** °F. This cooler has negligible pressure drop.

I. The cumene column (CUM-COL) consists of 10 theoretical stages, which include a total condenser ($P_{condenser}$ = 14 psia) and a reboiler ($P_{reboiler}$ = 14.5 psia). The feed tray location is 5. The column takes out 20 mol% of the feed as the overhead distillate and operates with a molar reflux ratio of 3.

J. The cumene product stream from the second column must contain a purity of **99.*X*** mole% cumene (product spec).

How to specify x (cumene purity) & y (cooler exit temperature)

1. Suppose your roll number is CH17xabc.
2. Calculate T=(a+b+10*c)
3. *X* = T mod 9
    a. (i.e., x is remainder after dividing T by 9)
4. *Y* = T mod 19

Hints

A. For properties, use NRTL-RK and declare nitrogen and oxygen as Henry's law components.
B. Also, remember to select APV732 HENRY-AP as a databank to search in Methods Binary Interaction HENRY-1 folder; otherwise, these Henry's law binary parameters between the two light gases and the solvents will not be loaded.
C. Although the cumene reaction occurs in the gas phase, you must specify Valid Phases = Vapor-Liquid in RPLUG because the generation of cumene may cause liquid to form inside the reactor.

Deliverables (DUE DATE: 27 Feb 2022, 11:00pm)

1. Use ASPEN PLUS to simulate this cumene production process.
2. Conduct a sensitivity analysis and generate a plot of the variation of the cumene product flowrate with the preheater temperature.
3. Create a PFD for the process clearly showing all the pumps that will be needed in the process. The PFD should include the stream table.