Exam. Code: 0907
Sub. Code: 6691

2021
B.E. (Biotechnology) Third Semester
BIO-311: Process Calculations

Time allowed: 3 Hours Max. Marks: 50

***NOTE**: Attempt five questions in all, including Question No. I which is compulsory and selecting two questions from each Section. Use of psychometric chart and steam tables is allowed.*

x-x-x

Q.1 a) Steam at a flow rate of 1500 kg/h, 5 bar and 200 °C flows through a pipe of diameter 77.927 mm. Calculate the velocity of steam in the pipeline.

b) Explain the terms single pass conversion and overall conversion.

c) 10 kg of liquid A of specific gravity 1.17 is mixed with 5 kg of liquid B of specific gravity 0.83. Assuming that there is no volume change on mixing, what is the specific gravity of the mixture.

d) A closed tank contains 10 lb of water. If 100 Btu are added to the water. What is the change in internal energy of water?

e) An aqueous cellulose solution contains 2.5% cellulose by weight. How many kg of 1.2% solution is required to dilute 50 kg of the 2.5% solution to 2%? (2×5)

SECTION-A

Q.2 a) A stream of growth medium containing 60% glucose and 40% growth factor flowing at 550 kg/h was divided into two feed streams for different cell cultures. Two third of the growth medium was sent to first fermenter and the rest to second fermenter. Estimate the flow rates of glucose and growth factor in the feed streams for the two fermenters. (5)

b) 200 kg of fresh milk containing 85% water and the rest milk solids is condensed using an evaporator to remove 75% of the water from the fresh milk. Calculate (i) the mass of water evaporated (ii) mass and composition of the condensed milk produced. (5)

Q.3 a) Heat transfer coefficient for fluids flowing through long tubes is expressed by the empirical equation $h\ (\frac{Btu}{hft^{2\circ}F}) = \frac{0.023\ G^{0.8}\times k^{0.67}\times {C_p}^{0.33}}{D^{0.2}\times \mu^{0.47}}$ where G is mass velocity of fluid (lb/ft^2 s), C_p is heat capacity at constant pressure (Btu/(lb °F), k is thermal conductivity (Btu/h ft °F), D is diameter of tube (ft) and μ is the viscosity of fluid (lb/ ft s). Convert the empirical equation in cgs units. (6)

b) 200 kg of sodium chloride is mixed with 600 kg of potassium chloride. Find the composition of the mixture in (i) mass percentage and (ii) mole percentage. (4)

Q.4. Benzene and hydrogen are reacted to produce cyclohexane according to the reaction $C_6H_6 + 3H_2 \rightarrow C_6H_{12}$. 20% excess hydrogen is used in the fresh feed to carry out the process. The overall conversion of benzene is 90% and the single pass conversion through the reactor is (10)

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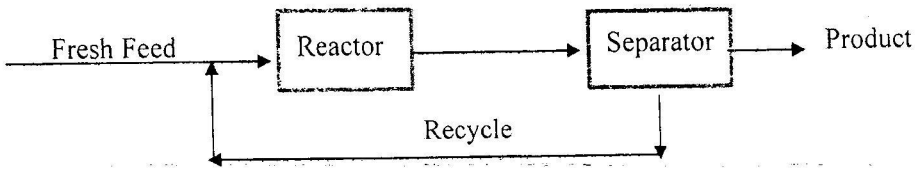
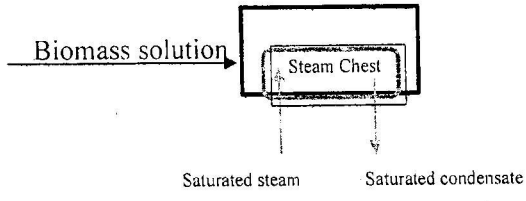
15%. The composition of the recycle stream is 22.47 mol% benzene and 77.53 mol % hydrogen. For the process shown in the figure determine (i) the composition of the product stream (ii) ratio of the recycle stream to the fresh feed. Explain the purpose of using recycle in a process.



SECTION-B

Q.5a) Saturated steam at 256°C enters the steam chest. The steam is segregated from the biomass solution in the preheater and is completely condensed in the steam chest. The rate of heat loss to the surroundings is 1.2 kJ/s. The material to be heated flows into the process vessel at 20°C and is at 45°C. If 120 kg of biomass with an average heat capacity (C_p) of 3.26 J/gK flows into the process per hour, how many kg of steam are needed per hour? (5)



b) The heat capacity of carbon dioxide is given by the relation (5)

$$C_{p_{CO_2}}(\text{kJ/kmolK}) = 26.540 + 42.454\times10^{-3}T - 14.298\times10^{-6}T^2$$

Calculate the heat required to heat 1 kg of CO_2 from 30 °C to 750 °C

Q.6 A stream of air at 31°C with a dew point of 14°C enters a textile dryer at a rate of 13.1 m^3/min and leaves saturated. The dryer operates adiabatically. Use the psychrometric chart to determine the absolute humidity and humid volume of the entering air. Determine the flow rate of dry air (kg/min) through the dryer, the final temperature of the air and the rate (kg/min) at which water is evaporated in the dryer. (10)

Q.7 Citric acid is manufactured using submerged culture of *Aspergillus niger* in a batch reactor operated at 30°C. (10)

$$Glucose + O_2 + NH_3 \rightarrow biomass + CO_2 + H_2O + citric\ acid$$

Over a period of two days, 2500 kg glucose and 860 kg oxygen are consumed to produce 1500 kg citric acid, 500 kg biomass and other products. Ammonia is used as nitrogen source. Power input to the system by mechanical agitation of the broth is about 15 kW; approximately 100 kg water is evaporated over the culture period. Estimate the cooling requirements. The heat of reaction at 30°C is -460 kJ/gmol O_2 consumed. Specific enthalpy of water at 30°C is 2430.7 kJ/kg.

x-x-x