Exam Date & Time: 02-Dec-2023 (09:30 AM - 12:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

THIRD SEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV 2023

BIOPROCESS CALCULATIONS [BIO 2125]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions. Section Duration: 180 mins

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) The viscosity of water is 1 centipoise (unit of poise is g/(cm*s)). Express the viscosity of water in Pa*S and $lb_m/(ft* h)$ (3)

A)

B) The heat capacity of carbon dioxide gas is given by $C_P = 0.1978 + 1.059 * 10^{-4} T – 2.395 * 10^{-8} T^2$

Where C_P is in Btu/(lb ^oF) and T is in ^oF. Change the equation into the form in which C_P is given in kJ/(kmol K) and temperature is in K. (4)

C) In normal living cells, the nitrogen requirement for the cells is provided from protein metabolism (i.e., consumption of the protein in the cells). When individual cells are commercially grown, $(NH_4)_2SO_4$ is usually used as the source of nitrogen. Determine the amount of $(NH_4)_2SO_4$ consumed in a fermentation medium in which the final cell concentration is 35 g/L in a 500 L volume of the fermentation medium. Assume that the cells contain 9 wt. % N. and that $(NH_4)_2SO_4$ is the only nitrogen source (Atomic weight of sulfur 32). (3)

2) A solution of potassium chloride in water contains 384 g KCl (MW = 74.5) per litre of the solution at 300 K. The specific gravity of the solution is 1.6. Calculate the following:

A) (a) The concentration in weight percent

(b) The mole fraction of KCl (4)

(c) The molarity of the solution

(d) The molality of the solution

B) If air consists of 77% by weight of nitrogen and 23% by weight of oxygen calculate:

(a) the mean molecular weight of air,

(b) the mole fraction of oxygen, (3)

(c) the concentration of oxygen in mole m^{-3} and kg m^{-3} if the total pressure is 1.5 atmospheres and the temperature is 25°C.

C) A mass flow rate m (g/s) is measured as a function of temperature T(°C) as follows:

$m = aT^{1/2} + b$.

T	10	20	40	80
m	14.76	20.14	27.73	38.47

(3)

Use a straight – line plot to verify this formula and determine a and b.

3) Skim milk is prepared by the removal of some of the fat from whole milk. This skim milk is found to contain 90.5% water, 3.5% protein, 5.1% carbohydrate, 0.1 % fat and 0.8% ash. If the original milk contained 4.5% fat, calculate its composition, assuming that fat only was removed to make the skim milk and that there are no losses in processing. (3)

A)

B) Oil seeds contains 49% oil, 40% pulp, 3% mineral salts and the rest moisture are leached with hexane as the solvent. The underflow from the leaching operation contains 25% hexane, 2.5% salts, 15% oil and 7.5% moisture. The extract contains 25% oil. The extract is distilled to recover entire oil from overflow solution. The underflow is subjected to steam distillation which recovers 95% hexane. For treating 100 kg seeds, calculate the following (3)

(a) The kilograms of hexane used

(b) The percent of hexane used that is recovered from the underflow.

(c) Percent recovery of oil from overflow solution.

C) Biological denitrification of nitrate containing waste waters can be described by the following overall reaction

NO_3^{-1} + a CH_3OH + H^+ -----> b $C_3H_7NO_2$ + c N_2 + d CO_2 + e H_2O (4)

(a) Determine a, b, c, d and e, if $Y_{X/S}$ = 0.5 g X/g N.

(b) Determine the degree of reduction of bacteria and methanol

4) Nitrobenzene (Mol. Wt 123) is produced commercially by nitrating benzene with a mixed acid containing 39 wt% nitric acid (Mol. Wt 63), 53 wt% sulfuric acid and 8 wt% water. A charge is made up of 655 kg benzene (Mol. Wt 78) and 1360 kg of mixed acid.

A)

$$C_6H_6 + HNO_3 \longrightarrow C_6H_5NO_2 + H_2O$$

(3)

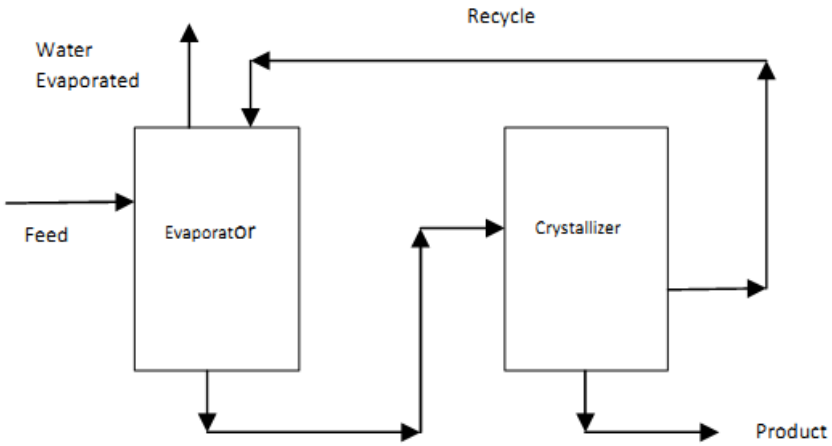
The reaction is 95% complete. Calculate

(a) The quantity of nitrobenzene produced

(b) Wt % of components in the product stream

B) A wet Biomass containing 5 wt % water is dried to 1 wt% water in a hot air dryer. Air containing 0.5 wt% water is fed to the dryer. The moist air leaving the dryer contains 2 wt% water. Find the flow rate of air required to dry 2000 kg/h of the wet Biomass. (3)

C) In a process producing KNO_3 salt, 1000 kg/h of a feed solution containing 10% KNO_3 is fed to an evaporator which evaporates some water to produce a 50% KNO_3 solution. This is then fed to a crystallizer, where crystals containing 95% KNO_3 are removed. The saturated solution containing 35% KNO3 is recycled to the evaporator. Calculate the following: (4)



(a) The amount of recycle stream, kg/h

(b) The amount of crystals, kg/h

(c) The quantity of water evaporated, kg/h

5) Briefly explain the principle of Liquid-Liquid extraction and draw the schematic diagram (3)

A)

B) A stream of nitrogen flowing at a rate of 100 k mole/h is heated from 303 K to 373 K. Calculate the heat that must be transferred. Molar heat capacity is given below in polynomial form as: (2)

$C_P(N_2) = 29.5909 - 5.141*10^{-3}\,T + 11.1829*10^{-6}\,T^2 - 4.968*10^{-9}\,T^3$

C) Propionibacterium species are tested for commercial-scale production of propionic acid. Propionic and other acids are synthesised in anaerobic culture using sucrose as substrate and ammonia as nitrogen source. Overall yields from sucrose as follows:

	% Yield (w/w)	Molecular Formula	Mol wt	Heat of combustion Δh_c^o
Propionic acid	40	$C_3H_6O_2$	74.1	-1527.3 kJ/gmol
Acetic acid	20	$C_2H_4O_2$	60.1	-874.2 kJ/gmol
Butyric acid	5	$C_4H_8O_2$	88.1	-2183.6 kJ/gmol
Lactic acid	3.4	$C_3H_6O_3$	90.1	-1368.3 kJ/gmol
biomass	12	$CH_{1.8}O_{0.5}N_{0.2}$	25.9	-552 kJ/gmol
sucrose		$C_{12}H_{22}O_{11}$	342.3	-5644.9 kJ/gmol
Ammonia		NH_3	17	-382.6 kJ/gmol

(5)

Stoichiometric Equation

$$C_{12}H_{22}O_{11} + b\,NH_3 = c\,CH_{1.8}O_{0.5}N_{0.2} + d\,CO2 + e\,H2O + f_1\,C_3H_6O_2 + f_2\,C_2H_4O_2 + f_3\,C_4H_8O_2 + f_4\,C_3H_6O_3$$

Bacteria are inoculated into a vessel containing sucrose and ammonia; a total of 30 kg sucrose is consumed over a period of 10 days. What are the cooling requirements?

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