BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2023-2024
CHE F211: Chemical Process Calculations
Mid-Semester Examination

Date: 12.10.2023 **Time: 9:00-10:30 AM** **Maximum Marks: 90**

***Note*:** The question paper consists of two parts. **Part A** and **Part B** are to be answered in separate answer books. Collect answer book for **Part B** after submitting **Part A** answer book.

PART – A (Closed Book)

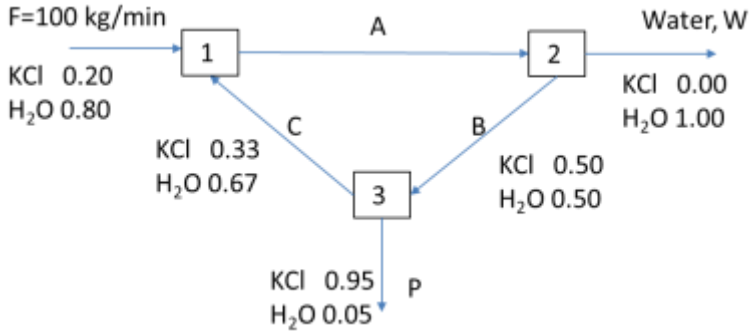
Time: 9:00 - 9.30 A.M. **Marks: 30**

1. **(6 Marks)** Classify the following processes as batch, continuous, or semi-batch and transient (unsteady) or steady-state:
   (a) Slowly blending several liquids in a tank from which nothing is being withdrawn.
   (b) Pumping a mixture of liquids into a distillation column at a constant rate and steadily withdrawing product streams from the top and bottom of the column.
   (c) Rapidly adding reactants to a tank and removing the products and unconsumed reactants sometimes later when the system has come to equilibrium.

2. (a) **(3 Marks)** A stack gas contains 60% N_2, 15% CO, 10% O_2 and the balance H_2O. Calculate the molar composition of the gas on a dry basis.

   (b) **(6 Marks)** A mixture of gases has the following composition by mass: O_2 16%, CO 4%, CO_2 17%, N_2 63%. What is its average molecular weight? Given atomic weights: C-12, O-16, N-14.

3. (15 Marks) For the system shown below, perform the degrees of freedom analysis and find the unknowns.



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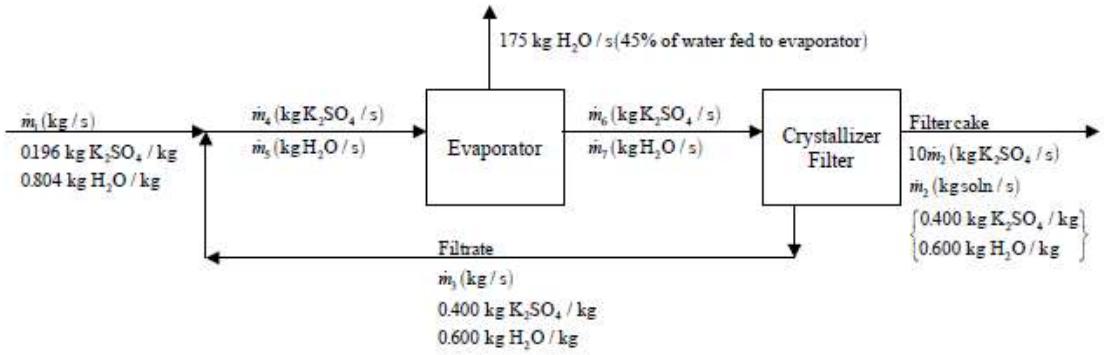
PART – B (Open Book)

Time: 9:30 – 10:30 A.M. **Marks: 60**

***Note*:** Only Text book (Himmelblau and Riggs, 7th/8th ed.) and hand-written class notes are allowed. Photocopies of class notes are not allowed.

1. (**20 *Marks***) The product gas from a solid fuel combustion reaction has the following dry-basis molar composition: 72.0% CO_2, 2.57% CO, 0.0592% SO_2, and 25.4% O_2. Pure oxygen is fed to the furnace in 20% excess of that required to burn the fuel completely. There is no oxygen in the fuel. Calculate the elemental composition (mole% of the various elements) of the fuel. Assume that there is no solid or liquid products obtained. Use elemental balance.

2. (**20 *Marks***) An evaporation-crystallization process is used to obtain solid potassium sulfate from an aqueous solution of this salt. The fresh feed to the process contains 19.6 wt% K_2SO_4. The wet filter cake consists of solid K_2SO_4 crystals and a 40.0 wt% K_2SO_4 solution, in a ratio 10 kg crystals/kg solution. The filtrate, also a 40.0% solution, is recycled to join the fresh feed. Of the water fed to the evaporator, 45.0% is evaporated. The evaporator has a maximum capacity of 175 kg water evaporated/s. Calculate the maximum production rate of solid K_2SO_4, the rate at which fresh feed must be supplied to achieve this production rate, and the ratio kg recycle/kg fresh feed.



3. (**20 *Marks***) Butane (C_4H_{10}) is burned with air. No carbon monoxide is present in the combustion products.
   (a) Use a degree-of-freedom analysis to prove that if the percentage excess air and the percentage conversion of butane are specified, the molar composition of the product gas can be determined.
   (b) Calculate the molar composition of the product gas for 20% excess air, 90% conversion of butane.

[Atomic weights: C-12, H-1, O-16, N-14]

All the best

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