EPFL |ChE-201 Introduction to Chemical Engineering| Midterm Exam Questions - 15th November 2024

Rules:

1. This exam is paper-based: no electronic material is allowed, at the exception of a calculator.

2. You have access to your notes and any supplementary material you brought.

3. You have 180 minutes to solve the exam.

4. You are required to show valid photo ID. Please place it visibly on your desk.

5. If you need to go to the bathroom, please raise your hand and we will accompany you.

Instructions:

1. Write your name on this question booklet and on all your answer sheets.

2. Answer all questions on your answer sheets or the question booklet.

3. At the end of the exam, turn in both the question booklet and all your answer sheets.

4. Please show all your work. Do not expect the grader to guess your reasoning. Your grade will depend on the reasoning that you used as well as the clarity and correctness of your answers.

5. There are three exercises in total, on the following topics: mass balance non-reactive, energy balance non-reactive, energy balance reactive If you are having difficulty on any question, you may wish to move on and return to the question later.

6. There are 100 scorable points in total. The number of points associated with each exercise is respectively indicated at the beginning of the exercise.

7. We wish you best of luck and much success!

First Name: _____

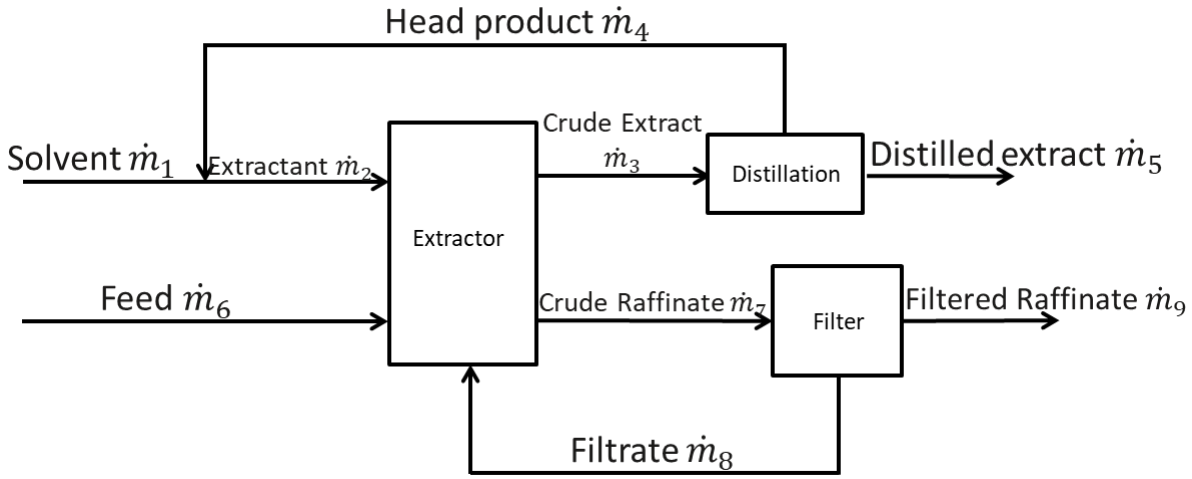
Last Name: _____

N ◦ SCIPER: _____

Problem 1: Mass Balance Non-Reactive (30 points)

Instructions:

Modern processing plants extract soybean oil by solvent liquid transfer. Extraction occurs by successive washes of hexane solvent. Below is a simplified diagram of the process. The beans are washed in an extractor using hexane. The oil and solvent mixture are then sent to a distillation column, where the oil is sent to storage and the hexane recycled back to the extractor. The washed beans are also sent to a filter to salvage residual hexane, which is then recycled back to the extractor.



Consider the following:

- Each 102kg of the feed of soybeans to the extractor contains 2 kg of oil.
- 5%w of feed oil remains in the crude raffinate leaving the extractor.
- For every 100kg of beans, 25 kg of Hexane leaves with the washed beans in the crude raffinate, of which:
  - 22kg is salvaged using a filter and sent back into the extractor.
  - the rest is discarded along with the filtered raffinate.
- Distillation head product and the crude extract contain only Hexane and Oil.
- The filtrate and the solvent supplied to the system contain only Hexane.
- The extractant entering the extractor contains 97%w Hexane.
- The crude extract entering the distillation column contains 87%w Hexane.
- The distilled extract that leaving the distillation column contains 8%w Hexane.

Questions:

a) Annotate the flow chart correctly with the information provided.
b) How much Solvent Hexane must be supplied per 100kg of Soybeans?

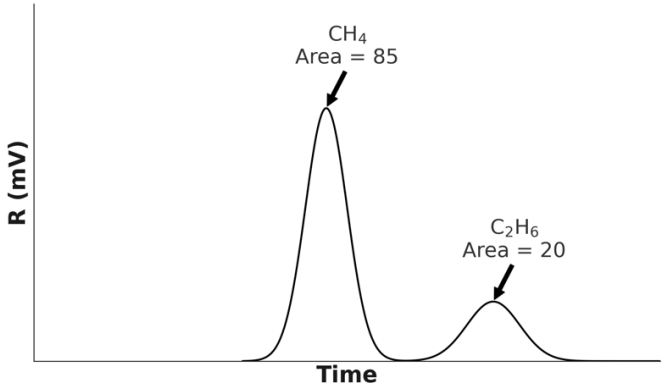
Name: ……

Problem 2: Mass Balance Reactive (35 points)

Instructions:

A stream of fuel gas containing methane (CH_4), ethane (C_2H_6), and carbon dioxide (CO_2) of unknown molar composition is **burned** with a stream of air in a continuous combustion chamber.

To analyze the fuel gas composition, a gas chromatograph (GC) and flame ionization detector (FID) were used; the GC separates the components of the gas, and the FID registers signals proportional to the amount of each carbon (except for CO_2) in its sample chamber. The output of the FID is as follows:



The area under each peak is proportional to the number of carbon atoms in the sample.

To ensure that the combustion of the fuel gas with air operates as expected, you use an air flowmeter which analyzes the molar feed ration of air to fuel. The air-to-fuel ratio is supposed to be 7:1. However, one of your colleagues mentioned that the air flowmeter might be inaccurate.

To investigate whether this is the case, you conduct an additional set of analysis: you take a 0.50 mol sample of the **product gas** resulting from the combustion of the fuel gas with air and pass it through a condenser, which condenses essentially all the water in the product gas sample. The condensate of the product gas (which can be assumed to be pure water) is weighed and found to have a mass of 1.134 g. The remaining of the product gas, i.e., the dry gas that leaves the condenser is then analyzed and found to contain no hydrocarbon (such as methane or ethane), no CO, and 11.9% CO_2.

Name: ……

Remarks:

- *Use 100 mol of product gas as the basis for calculations when necessary.*
- *Assume the composition of air is 21% O_2, 79% N_2.*
- *Remember that the chemical equation for stoichiometric combustion of a hydrocarbon in oxygen is as follows:*

$$C_xH_y + \left(x + \frac{y}{4}\right) O_2 \rightarrow x\ CO_2 + \frac{y}{2} H_2O$$

Questions:

(a) Calculate the molar ratio of C_2H_6 / CH_4 in the fuel gas.
(b) Define the combustion reactions taking part in the combustion chamber, draw and label a flowchart of the system.
(c) Calculate the molar composition of the fuel gas, and the desired percent of excess air.
(d) Calculate the actual molar feed ratio of air-to-fuel, and the actual percent of excess air.

Name: ……

Problem 3: Energy Balance Non-Reactive (35 points)

Instructions:

In the manufacture of nitric acid, ammonia and preheated air are mixed to form a gas containing 10.0 mole% NH_3 at 600°C. Ammonia enters the gas blending unit at 25°C at a rate of 520 kg/h and heat is lost from the mixer to its surroundings at a rate of 7.00 kW.

Check your physical tables and use **only the two first terms** of the expression for heat capacities (i.e., the terms *a* and *b*).

Questions:

a. Draw and label properly the flowchart. Include all the information required to perform the energy balances.
b. Define the temperature to which the air must be preheated.

Name: ……