ChE-201: Introduction to Chemical Engineering
Midterm Exam Questions
14 November 2025

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 in non-reactive and reactive systems, and energy balance in non-reactive systems, respectively. 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: ________________

SCORE

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

Instructions:

One of the best ways to reduce or eliminate hazardous waste is through source reduction. Generally, this means using different raw materials or redesigning the production process to eliminate the generation of hazardous byproducts. As an example, consider the following countercurrent extraction process that is shown in the figure to recover xylene from a stream that contains 10% xylene and 90% solids **by weight**.

The stream from which xylene is to be extracted enters Unit 2 at a flow rate of 2000 kg/h. To provide a solvent for the extraction, pure benzene is fed to Unit 1 at a flow rate of 1000 kg/h. The mass fractions of the xylene in the solids stream (F) and the clear liquid stream (S) have the following relations:

$$10\ \omega_{Xylene}^{F^1} = \omega_{Xylene}^{S^2}$$

$$10\ \omega_{Xylene}^{F^2} = \omega_{Xylene}^{S^1}$$

where ω_{Xylene}^{A} designates the mass fraction of xylene in stream A.

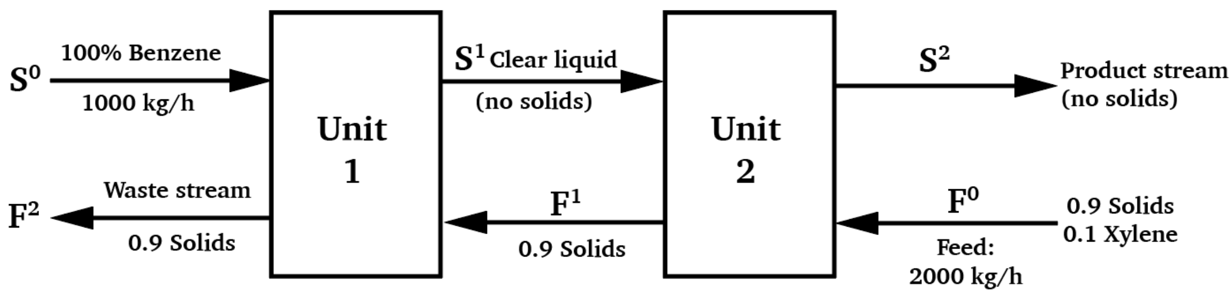

Figure 1.

Questions:

a) Determine the benzene and xylene concentrations in all the streams.

b) What is the percent recovery of the xylene entering the process at Unit 2?

<u>Hint</u>: Streams F^1 AND F^2 might also contain a certain amount of benzene.

Problem 2: Mass Balance, Reactive Systems (35 points)

Instructions:

Acetic acid can be produced via the reaction:

$$3\ C_2H_5OH + 2\ Na_2Cr_2O7 + 8\ H_2SO_4 \rightarrow 3\ CH_3COOH + 2\ Cr_2(SO_4)_3 + 2\ Na_2SO_4 + 11\ H_2O$$

In the recycle system shown in Figure 2, 90% overall conversion of C_2H_5OH is obtained with a recycle flow F4 equal to the feed rate of fresh C_2H_5OH in F1. The feed rates of fresh H_2SO_4 and $Na_2Cr_2O_7$ in F2 are 20% and 10%, respectively, in excess of the stoichiometric amounts required for the fresh C_2H_5OH feed F1. The recycle stream F4 contains 94 mole-% H_2SO_4 and the rest C_2H_5OH. All the CH_3COOH is separated and leaves in the top stream F6 of the separator.

Assume a feed rate of fresh C_2H_5OH of ***100 mol/h****.*

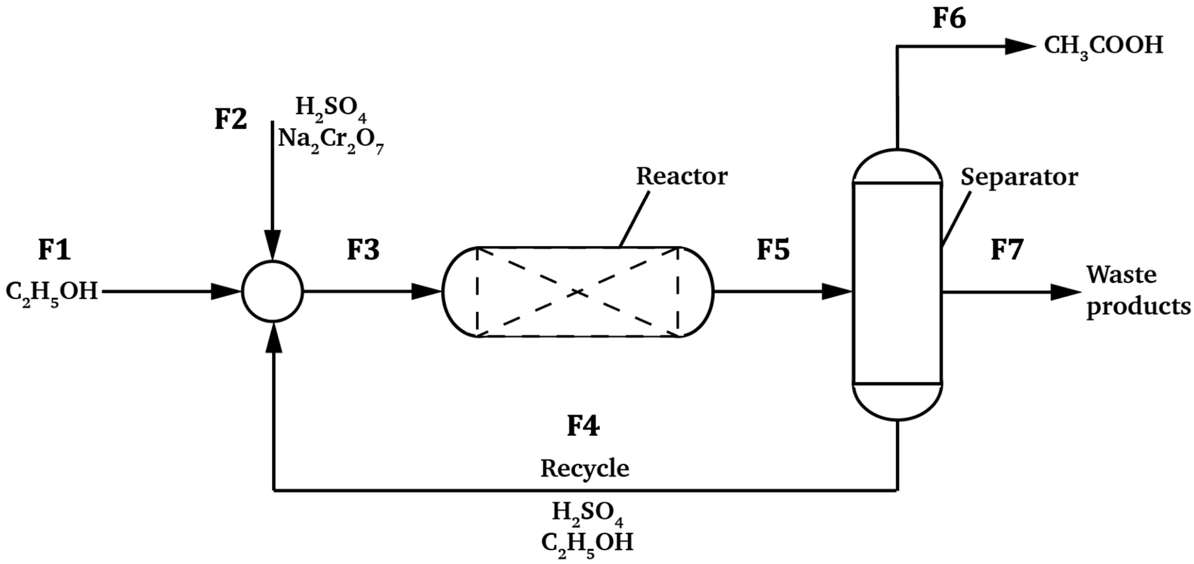

Figure 2.

Questions:

a) Draw and label a detailed flowchart of the process, recapitulating the composition of each stream.
b) Calculate the upper product stream flow F6.

c) Compute the flow rate of each stream, as well as the composition of each stream, and fill in the table below:

	F1	F2	F3	F4	F5	F6	F7
Flow rate (mol/h)	100						
$x_{C_2H_5OH}$	1					1	0
$x_{H_2SO_4}$	0						
$x_{Na_2Cr_2O_7}$	0						
x_{CH_3COOH}	0						
$x_{Cr_2(SO_4)_3}$	0						
$x_{Na_2SO_4}$	0						
x_{H_2O}	0						

d) Calculate the conversion of C_2H_5OH in the reactor.

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

Instructions:

A mixture (1) containing 65.0 mole% acetone (Ac) and the balance acetic acid (AA) is separated in a continuous distillation column at 1 atm. The overhead stream (2) from the column is a vapor that passes through a condenser. The condensed liquid is divided into two equal streams: one is taken off as the overhead product, the distillate (3), and the other, the reflux (4), is returned to the column. The bottom stream (5) from the column is a liquid that is partially vaporized in a reboiler. The liquid stream emerging from the reboiler is taken off as the bottom product (6), and the vapor is returned to the column as boil-up (7). Negligible heat is lost from the column, so that the only places in the system where external heat transfer takes place are the condenser and the reboiler.

Stream Data:

Stream	State	Temperature (°C)	Composition
Feed (1)	Liquid (l)	67.5	65 mole% Ac, 35% AA
Overhead (2)	Vapor (v)	63.0	98 mole% Ac, 2% AA
Distillate (3)	Liquid (l)	56.8	98 mole% Ac, 2% AA
Reflux (4)	Liquid (l)	56.8	98 mole% Ac, 2% AA
Bottom (5)	Liquid (l)	98.7	x mole% Ac, (100-x)% AA
Bottom product (6)	Liquid (l)	98.7	15.5 mole% Ac, 84.5% AA
Boil-up (7)	Vapor (v)	98.7	54.4 mole% Ac, 45.6% AA

The table reads as follows: stream (3), referred as Distillate, contains 98 mole % Acetone and 2 mole % Acetic Acid, both in a Liquid (l) state and at 56.8(°C)

Thermodynamic Data:

$\hat{H}$ (cal/mol)				
	Acetone		*Acetic Acid*	
T (°C)	$\hat{H}_l$	$\hat{H}_v$	$\hat{H}_l$	$\hat{H}_v$
56.8	0 (ref.)	7205	0 (ref.)	5723
63.0	205	7322	194	6807
67.5	354	7403	335	6884
98.7	1385	7946	1312	7420

The table reads as follows: at 63.0 °C, $\Delta\hat{H}_{acetone,v} = \hat{H}_{acetone,v} - \hat{H}_{acetone,l,ref} = \hat{H}_{acetone,v} - 0 = \hat{H}_{acetone,v} =$ 7322 cal/mol, where: v = vapor state and l = liquid state

Questions:

a) Draw and label the fully annotated flowchart for the problem.

b) Taking 100 mol/hour of feed as a basis, calculate the net heat requirement (in *cal*) for the process.

c) For the same basis, calculate the required heat input to the reboiler and the required heat removal from the condenser.