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**CBE 40 Midterm V3**
**October 7, 2020**
**75 minutes to complete and submit**

**This exam consists of 3 problems and is worth 100 points**

No communication with anyone inside or outside our class is permitted.
No use of outside materials other than a calculator is permitted.

Use appropriate significant figures in your answers.
Show all work and/or explain your reasoning. Scan and submit all your work pages on **Gradescope**. Write your name and section number on each page. If you have or anticipate any issues with submitting, let us know as soon as possible.
You must also submit your agreement to follow the **honor code** (first page of this exam) on Gradescope.

If you need to ask any **clarifying questions** during the exam, submit them on Piazza We will share any answers with the class by a bCourse Announcement. However, we will **not** be monitoring Piazza during these times (all PT) so plan accordingly:

Wednesday 11 pm - Thursday 7 am
Thursday 9:30 – 11 am
Thursday 11 pm - Friday 7 am
Friday 9 – 11 am

| *problem* | *points* | *possible points* |
|---|---|---|
| Honor Code | | 0 |
| 1 | | 35 |
| (1 - extra credit) | | 0 |
| 2 | | 35 |
| 3 | | 30 |
| TOTAL | | 100 |

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**Honor Code**

Please write and submit the following to indicate your agreement to abide by the UC Berkeley Honor Code:

*On my honor, I, [your name], have neither given nor received any assistance in taking this exam.*

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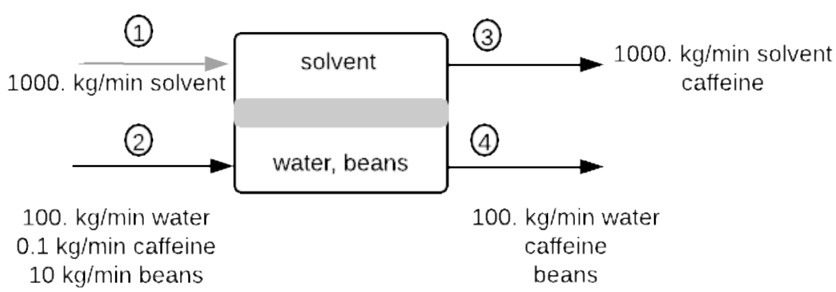
1. **Coffee decaffeination** *(35 points)*
Coffee beans can be decaffeinated by extraction (removal) of caffeine from a water phase into a solvent phase. The water phase and the solvent phase are immiscible (do not mix), and the used (dirty) solvent is recycled to another part of the process. *At equilibrium*, the relationship between the concentration of caffeine in the water phase and the concentration in the solvent phase is given by the empirical equation:

$[c]_W = K[c]_S$
$K = 4.0$ kg solvent/kg water

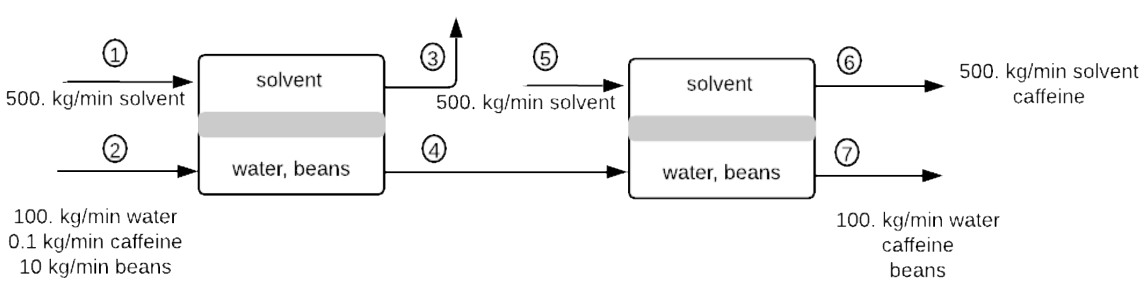
where $[c]_W$ is kg caffeine/kg water, and $[c]_S$ is kg caffeine/kg solvent. (For example, $[c]_{w,2}$ = .001. The concentrations are expressed this way instead of as weight percentages to make the calculations easier.)

Consider two options below: option (i) uses one extractor with 1000. kg/min of solvent; option (ii) uses 2 extractors with 500. kg/min of solvent each. Assume that the solvent and water streams leaving each extractor are *in equilibrium.* For each option, calculate the **flow rate (kg/min) of caffeine exiting the final extractor in the water phase**.

**option (i)**




**option (ii)**




**Option (i):** $F_{c,4}$ = _______ kg/min
**Option (ii):** $F_{c,7}$ = _______ kg/min

**Extra credit (5 points)**
What would the flowrate of caffeine exiting in the water stream be if a similar third extractor were added to option (ii)? _______ kg/min

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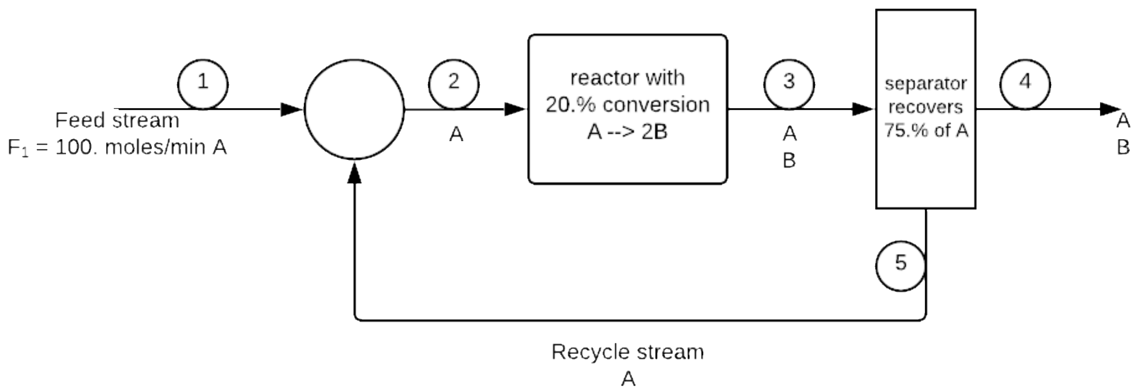
2. (*35 points*)
Compound A reacts by dissociation to form product B as follows:

$$A \rightarrow 2B$$

A feed stream of 100. moles/min of A is fed to the process as shown below. The reactor conversion is 20.%. A separator recovers 75% of the unreacted A and that stream is recycled to increase the overall conversion of the process.




a) Determine the flowrate of A in stream 2: $F_{A,2}$ = ____________ moles/min

b) Determine the flowrates of A and B in Stream 4: $F_{A,4}$ = ____________ moles/min
$F_{B,4}$ = ____________ moles/min

c) Determine the ***overall*** conversion of the process: conversion = __________%

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3. **Waste biomass to ethanol** (*30 points*)
Draw a PFD for the following process to convert a stream of pre-treated biomass from waste plant materials to ethanol. Label the components of each stream. Be sure to follow conventions for unit operations and process flow diagrams. For full credit include at least one recycle stream. You may neglect energy flows.

The pre-treated biomass is a solid composed of cellulose, xylose and non-reactive solids. This is first washed with water. Enzymes are added and the solid/water mixture is then sent to a **hydrolysis reactor** where the following reaction occurs:

$$cellulose \rightarrow glucose$$

The products are mixed with yeast and then transferred to a **fermentation reactor**. The yeast ferments all of the xylose and glucose to produce ethanol and $CO_2$:

$$xylose + glucose \rightarrow ethanol + CO_2$$

The $CO_2$ is completely separated after the reaction. (Assume it is insoluble in liquid.) A filtration step then separates residual solids (including enzymes and yeast cells) from the effluent; these solids are transported to another process. The water and ethanol are separated by distillation, yielding a product stream of 95% ethanol and a bottom stream of pure water. Assume all reactions go to completion (100% conversion).

You may use the following abbreviations to simplify your PFD:

| material | abbreviation |
|---|---|
| Cellulose | C |
| Xylose | X |
| Glucose | G |
| Non-reactive solids | N |
| Ethanol | EtOH |
| Water | $H_2O$ |
| Yeast | Y |
| Enzymes | E |