UNIVERSITY OF BORÅS

# Bioprocess design 7.5 ECTS

**Ladokcode:** TK741D
**The exam is given to:** Bioprocess design

**ExamCode:** _____

**Date of exam:** 2016-05-31
**Time:** 09:00-13:00

**Means of assistance:**
It is an open-book exam. Calculators, books and notes are allowed.

Attn: No material can be shared between the students. No computer or mobile phones can be used.

**Total amount of point on exam::** 40
**Requirements for grading:**

**Additional information:**

**Next re-exam date:**

*The marking period is, for the most part, 15 working days, plus up to 5 working days for administration, otherwise it's the following date:*

*Important! Do not forget to write the ExamCode on each paper you hand in.*

*Good Luck!*

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Exam in:

# Bioprocess Design

(Open book exam)

1) We are going to have a plant for production of biogas (methane and $CO_2$) from molasses (by-product of sugar industries) in a continuous process. Our molasses contains 50% sucrose sugar and has density of 1 g/ml. It is first diluted with water in a tank to obtain 10% sugar content and then pumped to digesting reactors in which the sugar is converted to biogas according to:

$$C_{12}H_{22}O_{11} + H_2O \xrightarrow{Bacteria} 6CH_4 + 6CO_2$$

Then, the biogas is moved by a pipeline to an upgrading system, in which the $CO_2$ is washed out by water to reach methane content of 97%. For the upgrading, the biogas is compressed to 10 bar, and injected to the bottom of a packed column, in which water is sprayed from the top. In this column, a major part of $CO_2$ is absorbed to water and the methane is purified to 97% that is named upgraded biogas. The water passes through a valve to reduce the pressure to 1 bar and then goes to another similar column, in which air is added from the bottom and the water releases the $CO_2$ to the air. The water is then pumped and recycled to the first column. If we add 10 tons molasses per day to this process: (20 p)

a) How much methane gas (in $m^3$) is produced from each ton molasses?
b) What (volumetric) percentage of methane is in the biogas coming out of the reactor?
c) How many $m^3$ upgraded biogas is produced in this process per hour and per year?
d) Draw a PFD of this process as complete as possible!
e) If the retention time of the substrate in the reactor would be 30 days, what would be the volume of the reactor?
f) Do we have wastewater in this process? How much per hour?
g) As molasses has high viscosity (similar to thick syrup), what types of pumps should we use to transport it? Why?

2) Production of PHB (a biopolymer) occurs inside bacteria, where the cells first grow and then the production of PHB is triggered by limitation of nitrogen or phosphate, while sugar is still available. Discuss about advantages and drawbacks of using: (12 p)
   a) Fed-batch process,
   b) Chemostat process with one or several reactors in series,
   c) Continuous process with cell recycling.
   d) What is your suggestion for this process?

3) A fixed tube heat exchanger should be designed for the following operating conditions: Process fluid in tubes requires stainless steel MOC, Shell side utility (cooling water) requires carbon steel MOC, Heat transfer area is 110 $m^2$, Operating pressure (both shell and tube) are 70 barg, CEPCI = 397 for 2001 and CEPCI = 580 for 2015: (8 p)

a) Determine the bare module cost of the heat exchanger in year 2001.
b) Estimate the price of the heat exchanger in year 2015.

Good luck! Buena suerte! Bonne chance! Viel Glueck ! よい運! Lycka till! الحظّ السّعيد! موفق باشيد

Mohammad Taherzadeh