

Midterm Exam for ChE 481: Biomass Conversion to Biofuels

Instruction: You have to work this exam INDIVIDUALLY. Please turn in your completed solutions before 3:30PM tomorrow (3/9/2012) in my mailbox located in Dana #118. When you turn in your solutions, please sign your name below and turn in it with your solutions.

With this signature, I testify that I did not give, obtain, or share my solutions with anyone else and I worked this exam individually. _____

1. Describe driving forces for biorenewable resources use in the U.S. to meet our current energy challenges. Define what biorenewable resources are and explain their classifications (with examples). Also define their main characteristics. Based on these defined biomass characteristics, describe some of challenges to biomass utilization for the alternative and sustainable energy productions.
2. Describe the main components and chemical make up of the plant cell wall. Discuss the impact of this composition on conversion of biomass to biofuels (e.g. ethanol).
3. The city of Pullman consumes approximately 6.41×10^6 kWh per day. If this energy came from a steam turbine which used the complete combustion of biogas (60% molar basis methane and the remainder carbon dioxide) in air to create the steam, how many moles of biogas would be needed each day to supply Pullmanites with their expected energy? The steam turbine has been found to be 30% efficient in its conversion of thermal energy to electrical energy and enthalpy loss due to the sensible heating is not negligible. For this problem, assume that reactants enter the boiler at 298k and exhaust gas leaves the boiler at 1,000k.
4. Using the same steam turbine generator as in the previous problem, please calculate how much of the local Palouse farmland would be needed to supply Pullman's energy requirements if wheat straw were being burned as a heat source for the generator. The heating value of wheat straw is 18.5 MJ per dry kg and the moisture content of wheat straw is ~20 wt.-%. Based on your calculation and assuming that the area of Whitman County is ~5,590 km², please briefly state if the local Palouse farmland is big enough to produce the required amount of wheat straw for providing the daily electrical power needs for Pullmanites.
5. For each of the following biobased transportation fuels, indicate the kind of engines in which they are targeted for use, their key properties relative to the fuels they are displacing, and the major feedstock currently used to produce them in the U.S.
 - (a) Ethanol
 - (b) Methyl Ester (i.e. biodiesel)
6. The glucose can be considered as one of important building blocks for a biobased economy. Please describe the chemical reaction steps needed to convert the glucose into lactic acid.
7. This problem is based on direct combustion and co-firing technology of biomass.
 - (a) List some of advantages and disadvantages of direct combustion technology of biomass for its conversion into the heat and power.
 - (b) The manager of a power plant in Pullman proposes to co-fire wheat-straw with coal as a means of reducing sulfur emissions from the plant. However, the plant engineer warns that alkali in the wheat-straw can lead to ash fouling in the boiler. The raw coal, which contains 0.1 wt-% of alkali,

has a heating value of 28 MJ/kg and sulfur content of 4 wt-%: (i) what is the maximum weight-percent of wheat straw that can be blended with the coal without producing ash fouling? (ii) what is the expected sulfur emission rate (kg/GJ) for the fuel blend?

8. This problem is based on the gasification of biomass

- (a) What are the key differences between the direct combustion and gasification reactions of biomass? Please explain your answers in terms of key products formed from and key reaction steps involved in each conversion technology.
- (b) Draw schematic diagrams of Updraft and Downdraft Gasifiers. For your schematics, clearly indicate different reaction zones. Based on your schematics, explain why Downdraft Gasifier would lead to a lower amount of tar comparing to that of Updraft Gasifier.

9. This problem is based on the anaerobic digestion of biomass

- (a) Show that the theoretical yield of methane from anaerobic digestion of cellulose is 27 wt-%.
- (b) It is estimated that one pig can generate 0.56 dry kg of manure per day. The owner of a swine facility containing 10,000 pigs proposes to produce biogas from the manure. Assuming volatile matter is 80% of the dry manure and 0.65 m³ of biogas can be produced per kg of volatile solids, estimate the daily methane production rate, (m³/day), and the annual energy production, (GJ/yr). The enthalpy of formation for CH₄ is 890,333 J/mol.