Lignocellulosic Biorefinery Test 1 given in 2019 (shortened)

1. (**10 points**) Furfural is a product which was already made by Quaker Oats in the nineteen twenties from oat husks. From which specific lignocellulosic polymer is it derived? Write the overall stoichiometric reaction equation.
2. (**20 points**) In principle it is possible to make propane (C_3H_8) from xylose by releasing its oxygen in the form of CO_2 and H_2O.

   a. What is the maximum theoretical mass yield of propane production from xylose?

   c. What is the maximum theoretical energy yield? The HHV of xylose and propane are 15.7 and 50.2 MJ/kg respectively.
3. (**10 points**) What are the approximate cross-sectional dimensions in nanometers of a cellulose microfibril? The external surface of these cellulose microfibrils are covered with a thin layer of hemicelluloses. What is the hemicellulose in softwoods and what is it in hardwoods?
4. (**10 points**) Pine heartwood requires a longer steaming time than pine sapwood to obtain a high degree of liquor penetration in industrial kraft pulping. Explain this phenomenon in mechanistic terms.
5. (**20 points**) 1000 metric tonne/day (bone dry basis) of softwood chips are processed using the AVAP (i.e. SO_2 in 50% (w/w) ethanol-water solution) process at a liquor to wood ratio of 3.0 L/kg (od), i.e. 1.5 L/kg for both ethanol and water (neglecting volume contraction upon mixing). During this fractionation process most of the wood lignin goes into solution as well as 6% (on wood) of xylan and 16% (on wood) of galactoglucomannan. Then all the ethanol and SO2 are evaporated sothat just the original water added remains. After a heat treatment all dissolved xylan and galactoglucomannan are fully hydrolyse into monosugars. Assume that all of the lignin which was solubilized during AVAP cooking again precipitates when ethanol and SO2 are evaporated. For the purpose of this problem the water consumed during sugar hydrolysis may be neglected, as well as volume changes due to the dissolved sugars.

   a. What is the concentration of xylose and the sum of galactose, glucose and mannose in this aqueous solution?

   b. How many gallons of ethanol can be produced theoretically per day from the C6 monomers in the evaporated solution. The density of ethanol is 0.79 g/cm^3 and an US gallon is 3.785 liter.

6. **(10 points)** During steam explosion and acid pretreatment of corn stover a significant amount of xylan is removed while most of the lignin remains in the pretreated corn stover. Explain why this is so. The relatively small amount of lignin which goes into solution presents an important technical problem. Briefly describe this problem.
7. (**10 points**) A graduate student wants to study a new pulping process. Because the research reactor is small, round wooden tooth picks of diameter 1.5 mm are used.
   How long should the tooth picks be steamed in order to accomplish 99% of the heating of the tooth picks? The tooth picks may be approximated by infinite cylinders.