Chemical Engineering 140 **October 29, 2007**

Midterm Examination #2

(140) 1. Acrylic acid ($C_3H_4O_2$) is formed via the oxidation of propylene (C_3H_6) in a two-step reaction as illustrated in Figure 1. Pure propylene (stream A) combines with a recycle stream (I) and enters the first reactor. Water and air in separate streams are fed into Reactor 1 as well. In the first reactor, propylene reacts with oxygen to form acrolein (C_3H_4O). The effluent stream of the first reactor is then fed into the second reactor where acrolein is completely converted to acrylic acid. The effluent of the second reactor is fed to a separator where all of the water and the acrylic acid are removed in one stream to form a stream of 40 mol % acrylic acid. The remaining material exits the reactor where 20% is purged and the rest is recycled back to the pure propylene feed. The composition of the purge stream (stream H) is 2.2% propylene, 10% oxygen and 87.8% nitrogen. The overall conversion of propylene is 80%.

Figure 1: Process flow diagram for oxidation of propylene to form acrylic acid

Reactions:

EMBED Equation.3

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(30)	How many moles of water to moles of propylene fed into the system must be added in order to achieve 40 mol% acrylic acid in the product output from the separator?
(30)	Calculate the molar recycle rate to the molar feed rate of pure propylene.
(30)	What is the single pass conversion of Reactor 1?
(30)	Determine the percent of excess air fed into the system.
(20)	Describe what you would do with the material purged from the separator.

(40) 2. A schematic of the Haber-Bosch process for producing ammonia is shown in Figure 2. Assume that clean fuel oil is available to substitute for the coke fed to the water-gas generator.

(25)	Write down the pertinent balanced chemical reactions taking place in the generator. You may assume that the hydrogen to carbon mole ratio in fuel oil is 2/1. Explain the purpose of each reaction.
(15)	In what form is ammonia finally produced in the Haber-Bosch process shown in Figure 2?

Figure 2: Haber-Bosch process