Practice Set 2

1. Methanol is produced by reacting carbon monoxide and hydrogen. A fresh stream containing CO and $H_2$ joins a recycle stream and the combined stream is fed to a reactor. The reactor outlet stream flows at a rate of 350 mol/min and contains 10.6 wt% $H_2$, 64.0 wt% CO and 25.4 wt% $CH_3OH$. This stream enters a cooler in which most of the methanol is condensed. The liquid methanol condensate is withdrawn as product, and the gas stream leaving the condenser, which contains CO, $H_2$ and 0.40% uncondensed $CH_3OH$ vapor, is the recycle stream that combines with the fresh feed. Calculate the molar flow rates of the CO and $H_2$ in the fresh feed, the production rate of liquid methanol, the single pass conversion of the reactor as well as the overall conversion, both for CO. Ans: Molar flow rate CO 32.1 mol/min, H2 64.2 mol/min; 32.1 mol/min methanol formed; 100% overall conversion, 25.1% single pass.

2. In a liquid extraction process, acetic acid is extracted from a mixture of acetic acid and water into 1-hexanol. In other words, two streams come into the extractor, one with acetic acid and water and the other is 1-hexanol. Some of the acetic acid will dissolve into the 1-hexanol, but the water will not. Therefore, leaving the extractor you have two streams, one with 1-hexanol and acetic acid, the other with water and acetic acid (hopefully with a lower concentration of acetic acid than the entering water/acetic acid stream!). The entering acetic acid/water stream has a flow rate of 400 g/min and is composed of 11.5 wt% acid. The exiting extract contains 9.6 wt% acetic acid, balance 1-hexanol and the exiting raffinate stream contains 0.50 wt% acid and balance water. Calculate the flow rates of the entering 1-haxanol and the extract and raffinate streams. Ans: 416 g/min hexanol; 461 g/min extract; 356 g/min raffinate

3. Seawater containing 3.50 wt% salt passes through a series of 10 evaporators. Roughly equal quantities of water are vaporized in each of the 10 units and then condensed and combined to obtain a product stream of fresh water. The brine leaving each evaporator except the $10^{th}$ is fed to the next evaporator. The brine leaving the $10^{th}$ evaporator contains 5.00 wt% salt. Draw a flow chart showing the $1^{st}$, $4^{th}$ and $10^{th}$ evaporators. Label everything. Determine the fractional yield of fresh water in the process (kg water recovered per kg of water fed to the process) and the weight percent salt in the solution leaving the $4^{th}$ evaporator. Ans: 31% fractional yield; 3.98 wt% salt in $4^{th}$ evaporator.

4. Calculate the composition of the stack gas on a dry basis if a fuel of composition $C_{0.71}H_{1.1}O_{0.003}$ containing 2.0 wt% sulfur species is combusted with 18% excess air (based on oxidation of the C and H only, i.e. not S) assuming complete combustion of the entering species (including S). What is the ppm of $SO_2$ exiting? Repeat with excess air of 36%.

5. A coal feed analysis shows that it is composed of 75 wt% C, 17% H, 2% S and the balance as noncombustible ash. The coal is burned at a rate of 5000 kg/h and the feed rate of air to the combustion process is 50 kmol/min. All of the ash and 6.0% of the C leave the furnace as molten slag, the rest of the C leaves through the stack has as CO or $CO_2$. All of the H is oxidized to $H_2O$ and all the S to $SO_2$. The selectivity of $CO_2$ to CO is 10:1. Calculate the % excess air into the reactor, the mole fractions of CO and $SO_2$ in the stack gas. If all the $SO_2$ is converted to sulfuric acid in the environment (acid rain), how much acid (kg/h) would form?