Chemical Engineering 201
Fall 1999
Final Exam

Name _____

Problem # 1 _____

Problem # 2 _____

Problem # 3 _____

Problem # 4 _____

Problem # 5 _____

Problem # 6 _____

Problem # 7 _____

Problem # 8 _____

Total _____

Problem #1 (30 points)
One liter of ethanol (vodka) is mixed with one liter of water (orange juice) in an insulated container. The ethanol is originally at 77 ^{o}F, while the water is at 40 ^{o}F. What is the final temperature of the mixture, ignoring evaporation and the heat of mixing?

Problem #2 (30 points)

Cumene is produced by reacting benzene with propylene in a fixed bed catalytic reactor. A liquid feed containing 75 mole % propylene and 25 mole % butane and a second liquid stream containing pure benzene are fed to the reactor. Fresh benzene and recycled benzene, both at 77 ^{o}F, are mixed in a 1:3 ratio and passed through a heat exchanger where they are heated by the reactor product stream before being fed to the reactor. The reactor product stream enters the heat exchanger at 400 ^{o}F and leaves at 200 ^{o}F.

After being cooled in the heat exchanger, the reactor product stream is fed to a distillation column. All of the butane and unreacted propylene are removed as the overhead product from the column, and the cumene and unreacted benzene are removed as bottoms product and fed to a second distillation column where they are separated. The benzene leaving the top of the second column is the recycle that is mixed with the fresh benzene feed.

The production rate of cumene is 120 lb_m/hr.

Draw a flowchart for the process and label everything that you know.

Problem #3 (30 points)
1000 kilograms of toluene per hour is heated from 25 ^{o}C to 100 ^{o}C in a heat exchanger. How much steam is needed per hour if the inlet steam comes in at 10 bar as saturated steam and leaves as saturated liquid. You may assume that the pressure does not drop in the heat exchanger and that the heat exchanger is adiabatic.

Problem #4 (30 points)
Water is contained in a large tank under a pressure of 4.0 bars (absolute). When a valve on the bottom of the tank is opened, the water drains freely through a 1 cm ID tube, whose outlet is 7 meters below the surface of the water. The pressure at the outlet of the discharge tube is 1 atm. What is the discharge velocity of the water and flowrate in liters/minute when the valve is fully open? You may neglect the rate of fall of water in the tank and any energy losses due to friction.

Problem #5 (30 points)
An adult takes roughly 12 breaths per minute, inhaling about 500 cm^3 of air with each breath. The exhaled air is saturated with water vapor at body temperature, which is 37 ^oC. Oxygen and carbon dioxide are exchanged in the lungs and the amount of nitrogen exhaled is equal to the amount inhaled. The mole fraction of the nitrogen in the expired air is 0.75. Estimate the mass of water that a body loses by breathing during a typical 24 hour period in Tucson, Arizona where the temperature of the inhaled air is 37 ^oC with a relative humidity of 10%.

Problem #6 (30 points)

Gaseous normal heptane is dehydrocyclicized catalytically to toluene in a hydrogen forming process:

$$C_7H_{16} \rightarrow C_6H_5CH_3 + 4H_2$$

The reaction takes place in an isothermal reactor where both the feed and the products are at 400^{o}C. If 10 mol/h of pure n-heptane are fed to the reactor and a 35% conversion is achieved, how much heat must be added to or removed from the reactor? Assume the heat capacity of n-heptane is 210 J/mol ^{o}C.

Problem #7 (30 points)
A stream containing 25 wt% methanol in water is to be diluted with a second stream containing 10% methanol to form a product containing 17 % methanol. What feed rate of the 10% solution is needed to produce 1250 kg/hr of the product?

Problem #8 (30 points)
One-half pounds of CO_2 are in a 5 ft^3 tank. The maximum pressure in the tank can be 14 psig due to safety concerns. What is the highest temperature the tank could be heated to in ^oF?