Problem Set A

Problems 1 to 4 due Wednesday, February 13, 2002

Problem 1

a) A paint mixture containing 25 % of a pigment and the balance water sells for $18/kg, and a mixture containing 12 % pigment sells for $10/kg. If a paint retailer produces a blend containing 17 % pigment, for how much ($/kg) should it be sold to yield a 10 % profit?

b) Strawberries contain about 15 wt% solids and 85 wt% water. To make strawberry jam, crushed strawberries and sugar are mixed in a 45:55 mass ratio, and the mixture is heated to evaporate water until the residue contains one-third water by mass. Draw and label a flowchart of this process, and, calculate how many pounds of strawberries are needed to make a pound of jam.

Problem 2

The waste acid from a nitrating process contains 23% HNO_3, 57% H_2SO_4, and 20% H_2O by weight. This acid is to be recovered as a usable product that contains 27% HNO_3 and 60% H_2SO_4 by the addition of concentrated sulfuric acid containing 93% H_2SO_4 and concentrated nitric acid containing 90% HNO_3. Sketch the process, and calculate the weights of waste and concentrated acids that must be combined to obtain 100 kg of the desired mixture.

Problem 3

The Haber process generates ammonia (NH_3) from nitrogen (N_2) and hydrogen (H_2). In this reaction, the feed nitrogen must be oxygen- and water-free. Air containing 21 mole-% oxygen and the balance nitrogen provides a cheap and convenient feedstock for the nitrogen used in the process. Sketch a flowsheet for the generation of ammonia using air and hydrogen that uses the combustion of hydrogen and oxygen as a means to deoxygenate air, a separation unit to remove water from nitrogen, and a reactor that combines oxygen/water-free nitrogen with hydrogen to produce ammonia. Determine the moles of hydrogen and air required as inputs per mole of generated ammonia, and determine the percentage of hydrogen that is incorporated in the product ammonia. You may assume a 100% conversion for all reactions.

Problem 4

Implants for the delivery of drugs are frequently implanted under the skin at an arm or leg (i.e., an extremity). The concentration of the drug in these regions is difficult to measure due to problems associated with the collection of sufficient amounts of blood from these areas as the capillaries that carry the blood are small.

As an indirect method for obtaining this information, a radioisotopic label is added to the drug used in the implant and the amount of radioactivity in the urine is measured. In this analysis, we

assume that no radiolabel is lost, the body is in homeostasis (there is no accumulation of drug or degraded products), and only degraded product is eliminated through the kidneys.

The following grossly simplified flow chart applies:

Water intake

Liver

Extremity ← Kidney

Implant release → Extremity

Kidney → Urine
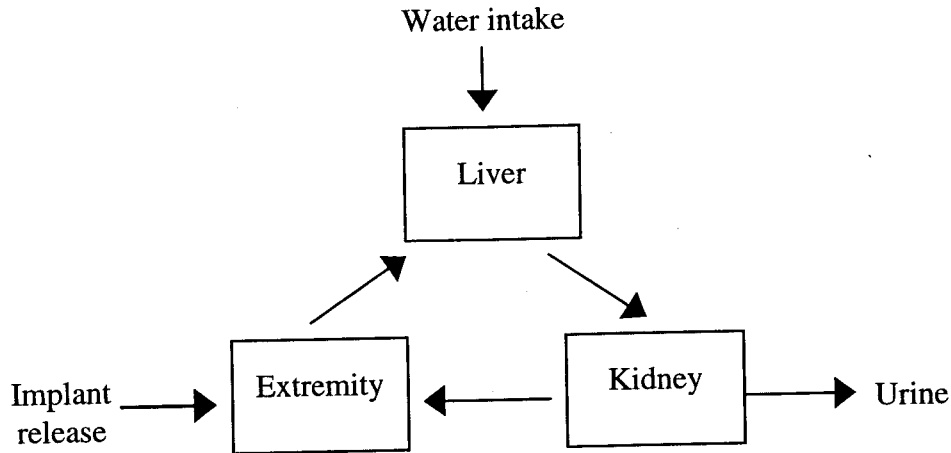
In this flow chart, the blood flows through the extremities where it picks up drug from the implant, then to the liver where half of the drug is degraded into degradation products, and finally to the kidneys where 10% of the degraded products are excreted. The total blood flow between the liver and kidney is estimated to be 6600 cc/hour. The measured output of urine is 30 cc/hr and contains 99.9 vol % water and 0.1 vol % degraded products.

a) Estimate the rate at which the implant releases drug into the extremities.
b) Estimate the volume of drug in the flow between the kidneys and the extremities.

Additional Practice Problems (not to be handed in)

Practice Problem P1
An acetone/methanol solution containing 75 mol % acetone is heated to a temperature where a liquid and vapor phase coexist. The vapor phase contains 85 mol % acetone while the liquid phase contains 50 mol % acetone. For a flow rate of 100 mol solution/hr, determine the flow rates of the liquid and vapor streams exiting the separation chamber.

Practice Problem P2
To provide an inert atmosphere to purge a reactor vessel, methane is burned in air to produce a mixture of CO_2, H_2O, and N_2. Determine what mass ratio of air to methane should be fed to the burner to provide such a gaseous mixture. Assume that air is 23% by mass O_2 and the remainder is N_2.