Chemical Engineering 140 **October 2, 2013**

Midterm Examination #1

(115) 1. A systemic cancer drug is taken orally as illustrated in Figure 1. The drug quickly dissolves in the stomach cavity (taken as a well-mixed cylindrical tank of diameter D) initially filled with aqueous broth to form a dilute aqueous solution of concentration C_o. Initial height of liquid broth is h_o. Stomach fluid continually drains into the intestine at a constant volumetric flow rate, Q_o. The drug, however, can also leave through the side walls of the cylindrical stomach at a rate per area $r_A = kC$, where k is a constant and $C = C(t)$ is the concentration of drug in the stomach at time t. Please note, kC has units of mass/time/submerged surface area. Let $A(t)$ be the surface area through which drug is leaving the stomach wall for the bloodstream. To be clear, while the drug can leave both to the intestine and through the liquid-exposed stomach wall to the bloodstream, stomach broth only flows out through the intestine.

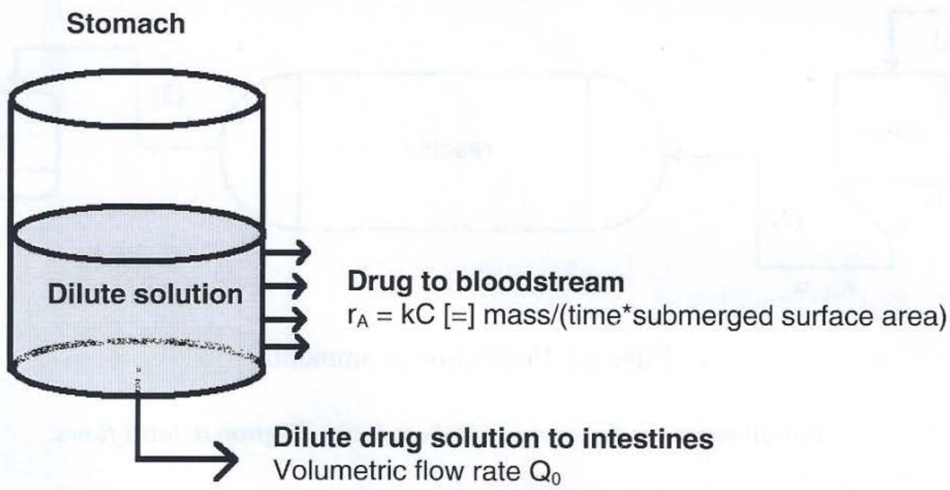

Figure 1. Drug absorption into bloodstream and loss to intestine.

(30) a.) Find an expression for the height of stomach liquid broth, $h(t)$, as a function of time.

(25) b.) Assume the diameter of the stomach is 10 cm, the height of the stomach is 40 cm, and the stomach is initially 10% full, $Q_o = 1.3$ cm^3/min, $C_o = 0.5$ g/L, and $k = 0.04$ cm/min. How long does it take the stomach to drain completely?

(30) c.) Write the mass balance for the drug in terms of the dependent variables C, h. Keep all constants as symbols.

(20) d.) Utilize the mass-balance equations from parts a and c to determine a differential equation for the concentration of drug in the stomach with respect to time (*dC/dt*) that contains only *C, t,* and constants.

(10) e.) Solve the differential equation from part d) to find the concentration of drug in the stomach as a function of time.

(105) 2. The Haber process has been used industrially since 1913 to produce ammonia continuously from nitrogen and hydrogen. Hydrogen gas and air at 450.0°C and 200.0 atm are fed to a mixer in a 2 to 1 ratio. The mixed stream is fed to a reactor, which achieves 15 % conversion of nitrogen. To purify the ammonia, the product from the reactor is fed to a condenser that recovers 95 % of the ammonia in its feed as a pure liquid.

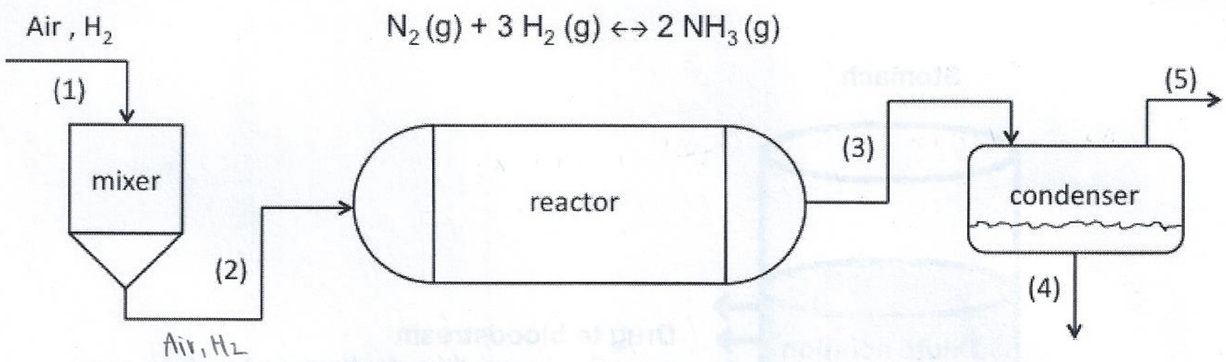

Figure 2. Production of ammonia.

For all parts use the stream numbers in the diagram to label flows.

(15) a. State the chosen basis for your balances.

(50) b. Calculate the composition of stream 3 out of the reactor. Carefully state your mass or mole balances.

(20) c. For a total molar flow rate in stream 1 of 60.7 kmol/h, calculate the molar flow rate of liquid ammonia out of the condenser.

(20) d. If the density of liquid ammonia is 5.69 lb_m/gal, what is the volumetric flow rate of ammonia out of the condenser, again for a total molar flow rate in stream 1 of 60.7 kmol/h?