BEL 102: Bioprocess Calculations
Major Examination

Time: 2 hours | Max. Marks: 40

Pay attention to the units. Express your answers in specified units only.

1. An thermophillic organism converts two-thirds (wt/wt) substrate carbon in hexadecane to biomass via the following stoichiometric reaction:

$$C_{16}H_{34} + a\ O_2 + b\ NH_3 \rightarrow c\ M + d\ H_2O + e\ CO_2$$

   (a) Calculate the stoichiometric coefficients and $Y_{X/O2}$ (g dw cell/ g O_2) for the reaction.

   (b) 0.5 moles of hexadecane is consumed inside a 15 L reactor (total volume) resulting in a pressure of 3.00 bars and temperature of 90°C inside the reactor. What is the volume of the head space in the reactor (space not containing liquid), assuming (i) all the carbon dioxide formed is in vapor phase, (ii) ideal gas behavior in the head space and (iii) only carbon dioxide as the vapor phase constituent remaining in the reactor. How much heat must be transferred to cool down the carbon dioxide to 30°C?

(5+5 = 10)

2. The synthesis of methanol from carbon monoxide and hydrogen is carried out in a continuous vapor-phase reactor at 5.00 atm (absolute). The feed contains carbon monoxide and hydrogen in stoichiometric proportion and enters the reactor at 25°C and 5.00 atm at a rate of 17.1 m^3/hr. The product stream emerges from the reactor at 127°C. The rate of heat transfer from the reactor is 17.05 kW. Calculate the fractional conversion achieved and the volumetric flow rate (m^3/hr) of the product stream.

(5+3 = 8)

3. Calculate the kinetic energy changes in an adiabatic turbine when superheated steam at 40 bars and 450°C flows at a rate of 15000 kg/h to the turbine, where it expands to 5 bars. The gas performs 358.51 kcal/s of work on the turbine. The turbine inlet and outlet pipes both have diameters of 0.5m. Given that kinetic energy changes below 0.25 kW can be neglected, determine the outlet steam temperature from the turbine. Results should be expressed in kW, wherever applicable.

(3+2 = 5)

4. A sulfuric acid solution (50 moles water per mole sulfuric acid) is neutralized with a sodium hydroxide solution (20 moles water per mole sodium hydroxide) in a continuous reactor. All reactants enter at 25°C. The standard heat of solution of sodium sulfate is -1.2 kJ/mol of sodium sulfate, and the heat capacities of all solutions (kJ/g.°C) may be taken to be that of pure liquid water.

   (a) Calculate the heat [kJ/kg H_2SO_4(aq)fed] that must be removed if the product solution emerges at 40°C.

   (b) Calculate the product solution temperature if the reactor is adiabatic.

(10+2 = 12)

5. An 8 M HCl solution (SG = 1.12, C_p = 0.66 cal/g.°C) is produced by absorbing HCl(g) in water. Liquid water enters the absorber at 25°C, and gaseous HCl is fed at 130°C and 820 mm Hg (absolute). The HCl emerges at 40°C. Estimate the volume (liters) of the gas that must be fed and the heat (kJ) that must be removed from the absorber per liter of product solution. Assume all HCl is absorbed.

(5)