B.E Food Technology and Biochemical Engineering
First Year, Second Semester 2017

Subject: Chemical Engineering Fundamentals **Time: 3 hrs** **Full Marks: 100**

PART I

Use separate answer script for each part
Answer any <u>three</u> questions

1.(a) Convert $\frac{7(in)(cm^2)}{(yr)(s)(lbm)(ft^2)}$ to all SI units. 12

(b) The equation for the velocity of a fluid steam measured with a Pitot tube is $v = \sqrt{\frac{2\Delta p}{\rho}}$ where v = velocity of fluid, Δp = pressure drop, ρ = density of the fluid. Is the equation dimensionally consistent? If the pressure drop is 20 mm Hg and the density is 1.35 g/cm^3, calculate the velocity of the fluid in ft/s. 8

2.(a) A wet food containing 60% water is fed to a dryer at a rate of 520 kg/hr. How much water is to be evaporated per hour so that the product contains 35% water? 10

(b) To prepare a solution of 50% H_2SO_4 acid a dilute waste acid containing 26% H_2SO_4 is fortified with a purchased acid containing 95% H_2SO_4. How much acid must be purchased for 100 kg of the dilute waste acid? 10

3. Hydrogen free coke containing 84% carbon by weight and the rest inert materials is burnt in a furnace. It is found that during combustion 5% of the coke charged is lost unburnt. The fine gas analysis shows 14.84% CO_2, 1.65% CO, 5.16% O_2 and 78.35% N_2. The flue gas leaves the furnace at 500 K and 1000 kPa. Calculate the following:
(a) the percent excess air on the basis of complete combustion of coke
(b) the amount of air supplied (in kg moles) per kg of coke charged
(c) the mass (in kg mole) of flue gas per kg of coke charged
(d) the composition of the refuse from the furnace 20

4. A dryer is fed with wet solid to reduce the moisture content from 90% to 25%. The product leaving the dryer is admitted to an oven which further brings down the moisture to 4%. If the dryer can handle 1000 kg wet solid per day, calculate the following:
(a) the weight of product leaving the dryer and the oven per day
(b) the percentage of the original water that is removed in the dryer and the oven. 20

5.(a) State any one reason for a stream being recycled in the process industry. 2

(b) A feed stream containing 25% vitamin and the rest water is fed to a centrifuge at the rate of 100 kg/hr. After separation of water, the stream coming out of the centrifuge contains 40% vitamins. This stream is fed to a continuous filter from where the output stream contains 96% vitamins. A recycle stream from the filter containing 29% vitamins is mixed with the feed stream at the entry point to the centrifuge. Calculate the amount of the recycle stream in kg/hr. 18

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BACHELOR OF ENGINEERING (F.T.B.E) EXAMINATION, 2017

(1st Year -2nd Semester)

Chemical Engineering Fundamentals

Time: 3 hrs. Full Marks : 40

Part – II (Answer any two questions from this part; 20 x 2 = 40)

1. (a) Define the following with proper example : closed system, state function

   (b) What is 'standard heat of formation' of a compound?

   (c) What do you mean by 'Van't Hoff Box' ?

   (d) The sulphate process for the production of HCl is described by the equation : $NaCl+H_2SO_4 \longrightarrow Na_2SO_4 + HCl$. Calculate the heat of reaction and the consumption of coke oven gas for the production of 500kg HCl. The heat of formation in MJ/Kmol for NaCl , H_2SO_4 , Na_2SO_4 and HCl are -410, -815, -1390 and -95, respectively. The calorific value of coke oven gas is 19MJ/m^3. (3+3+ 2+ 12)

2. (a) A gas is confined in a cylinder by a piston . The initial pressure of the gas is 7 bar and the volume is 0.15m^3. The piston is held in place by latches in the cylinder wall .The whole apparatus is placed in a total vacuum. What is the energy change of the apparatus if the retaining latches are removed so that the gas suddenly expands to double of its initial volume? The piston is again held by latches at the end of the process.

   (b) If the same process as described above is repeated, not in vacuum but in an air at standard atmospheric pressure of 101.3 kPa, what is the energy change of the apparatus? Assume the rate of heat exchange between the apparatus and the surrounding air is slow compared to the rate at which the process occurs.

   (c) When a system is taken from state a to state b along a particular path acb, 100J of heat flows into the system and the system dos 40J of work. How much heat flows into the system along another path aeb if the work done by the system is 20J? The system returns from b to a along a path bda. If the work done on the system is 30J, does the system absorb or liberate heat? How much? (4 + 6 + 10)

3. (a) Determine the heat of reaction for the following at STP and state whether the reaction is endothermic or exothermic : $Na_2CO_3 + Ca(OH)_2 \longrightarrow CaCO_3 + NaOH$. Data given : ΔH_f^0 values for Na_2CO_3, $Ca(OH)_2$, $CaCO_3$ and NaOH are -288.5 , -102 , -270.3 and -235.8 kcal/g mol respectively.

   (b) Calculate the heat of reaction of the following at 600^{0}F and 1 atm pressure : $CO + H_2O\ (g) \longrightarrow CO_2 + H_2$

   Data given : ΔH_f^0 values for CO_2, H_2O and CO are -168918 , -122196 and -46722 Btu/lb mol respectively. Average molar heat capacities (C_p) of CO, $H_2O(g)$, CO_2 and H_2 are 7.07, 8.22, 10.11 and 6.97 Btu/lb mol , respectively; heat of condensation of steam is -970 Btu/lb ; specific heat of water is 1 Btu/lb-^{0}F. (5 + 15)

4. 10 m^3 of dry CO_2 at 200kPa and 40°C is to be fed into a chamber to cool it at 20^{0}C.The gas is inside a copper tube with an internal diameter of 25mm and wall thickness of 1.20mm surrounded by another copper tube with an internal diameter of 35 mm and wall thickness of 1.65mm. Water flows through the annular space at a velocity of 0.15 m/sec. Water enters at 15°C and flows counter current to the gas. Calculate the outlet temperature of water. Assume that specific heat for water is 4.19 kJ/kg-K and heat capacity (Cp) of CO_2 at a average temperature of 30^{0}C is 0.80 kJ / kg-K. (20)

5. A 500 gallon continuous stirred tank reactor (CSTR) is fed 2,780 lb_m /hr of feed at 70^0Fwith a concentration of 0.5 lb-mole of reactant A per ft^3. Some of the reactant a is consumed in the reactor , producing product b. The concentration of the reactant in the stream leaving the reactor is 0.245 lb-mole of A per $ft^3$and the temperature of this stream is 140^0F. the heat capacity of the reactant and the product are both 0.75 Btu/lb_m-^{0}F and their densities are both 50 lb_m/ft^3. The reaction is exothermic, giving of 30,000 Btu/lb-mole of a reacted. How much heat must be removed from the reactor ? if cooling water at 70^0F is fed into the cooling jacket surrounding the reactor and leaves the jacket at 118^0F, how much cooling water must be used? Assume 1 gallon of water to be 8.33 lb_m of water. (20)

6. An evaporator is to be fed with 1500kg/h of a fruit juice containing 6% solute by weight at a temperature of 40°C . It is to be concentrated to 10% solute by weight in the evaporator which is operating at 100kPa in the vapour space. The heating surface is supplied with saturated stem at 136kPa (saturation temperature is 108^0C).Calculate the weight of the vapour produced in the evaporator and the weight of the steam required at the heating surface. If the overall heat transfer coefficient of the evaporator is 1500w/m^2-K, calculate the required surface area for heat transfer. Assume other physical properties of the juice to be identical with those of pure water.

   Data given: Specific enthalpy of the fruit juice at 40^0C is 167.5kJ/kg and at 100^0C is 418.6kJ/kg

   Specific enthalpy of the vapour at 100^0C is 2675kJ/kg; Specific enthalpy of the saturated vapour at 108^0C is 2690kJ/kg and Specific enthalpy of the saturated water at 108^0C is 454kJ/kg (20)

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