# National Institute of Technology Hamirpur
## Department of Chemical Engineering
### End Term Theory Examination
### Subject: Chemical Process Calculations

**Class: B.Tech 2ⁿᵈ Year**                                    **Semester: 3ʳᵈ**
**Course code: (CHD-213)**                                   **(Total – 50 Marks)**
                                                              **Time: 2 h**

**All questions are compulsory**
**All questions carry equal marks**
**Write name, roll no and put signature at the end of each page of your answer script**
**Marks will be deducted for the late submission of answer script (within 12:10 PM)**
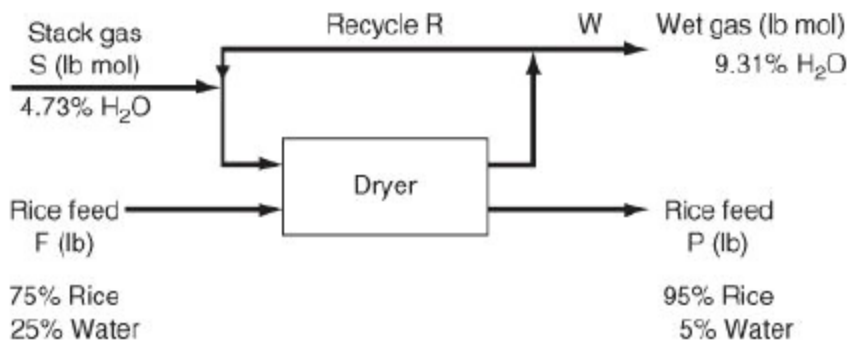
1. A) A liquid mixture of benzene and toluene is in equilibrium with its vapour at 101 kPa and 373 K. The vapour pressure of benzene and toluene at 373 K respectively are 165 and 63 kPa. Assuming that the system obeys Raoult's law, then what is the mole fraction of benzene in the liquid phase?

   B) If the percentage humidity of air (30ºC, total pressure 100 kPa) is 24% and the saturation pressure of Water vapour at that temperature is 4 kPa, what will be the percent relative humidity and the absolute humidity of air?                5+5

2. A reverse osmosis unit treats feed water (F) containing fluoride and its output consists of a permeate stream (P) and a reject stream (R). Let CF, CP, and CR denote the fluoride concentrations in the feed, permeate, and reject streams, respectively. Under steady state conditions, the volumetric flow rate of the reject is 60% of the volumetric flow rate of the inlet stream, and CF = 2 mg/L and CP = 0.1 mg/L.

   1. What will be the value of CR in mg/L?

   2. A fraction f of the feed is bypassed and mixed with the permeate to obtain treated water having a fluoride concentration of 1 mg/L. Here also the flow rate of the reject stream is 60% of the flow rate entering the reverse osmosis unit (after the bypass). What is the value of f?                                                                10

3. A) The following combustion reactions occur when methane is burnt.

   $CH_4 + 2O_2 = CO_2 + 2H_2O$

   $2CH_4 + 3O_2 = 2CO + 4H_2O$

20% excess air is supplied to the combustor. The conversion of methane is 80% and the molar ratio of CO to $CO_2$ in the flue gas is 1:3. Assume air to have 80 mol% $N_2$ and rest $O_2$. How much $O_2$ is consumed as a percentage of $O_2$ entering the combustor?    6

B) A flare is used to convert unburned gases to innocuous products such as $CO_2$ and $H_2O$. If a gas of the following composition (in percent) is burned in the flare—$CH_4$ 70%, $C_3H_8$ 5%, CO 15%, $O_2$ 5%, $N_2$ 5%—and the flue gas contains 7.73% $CO_2$, 12.35% $H_2O$, and the balance is $O_2$ and $N_2$, what was the percent excess air used?    4

4. To save energy, stack gas from a furnace is used to dry rice. The flowsheet and known data are shown in Figure shown below. What is the amount of recycle gas (in pound moles) per 100 lb of P if the concentration of water in the gas stream entering the dryer is 5.20%?  10



Stack gas
S (lb mol)
4.73% $H_2O$

Recycle R

W    Wet gas (lb mol)
9.31% $H_2O$

Dryer

Rice feed
F (lb)

Rice feed
P (lb)

75% Rice
25% Water

95% Rice
5% Water

5. A pump takes water at 60 °F from a large reservoir and delivers it to the bottom of an open elevated tank 25 ft above the reservoir surface through a 3 in ID pipe. The inlet to the pump is located 10 ft below the water surface, and the water level in the tank is constant 160 ft above the reservoir surface. The pump delivers 150 gal/min. If the total loss of energy due to friction in the piping system is 35 ft-lb$_f$/lb, calculate the horse power required to do the pumping. The pump motor set has an overall efficiency of 55%.    10