irla Institute of Technology & Science, Pilani
Hyderabad Campus
Chemical Engineering Department

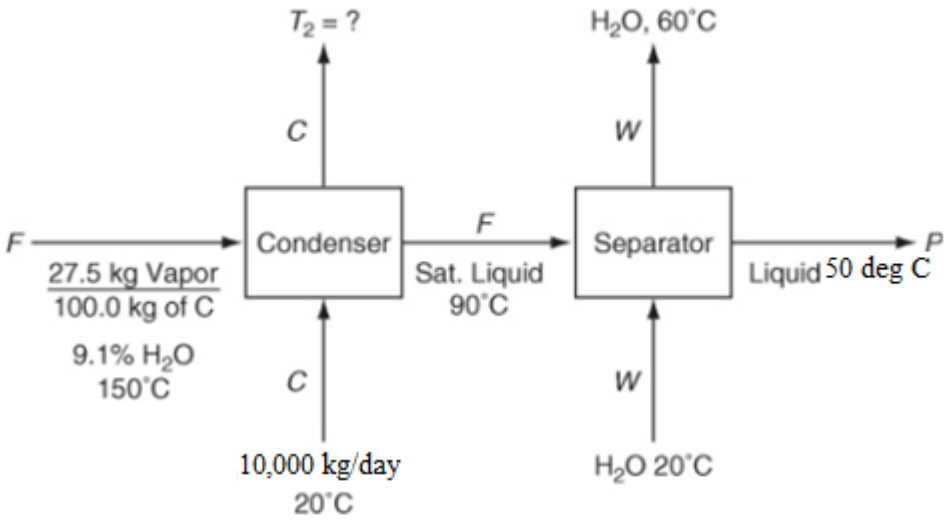
Comprehensive Examination

First Semester/2022-23

Course No.: CHE F211 **Time: 3h**
Course Name: Chemical Process Calculations **Weightage: 40%**
Instructor: Dr. Afkham Mir **Max Marks: 80**
Exam Type: Open Book

Attempt all questions. Make necessary assumptions wherever required.

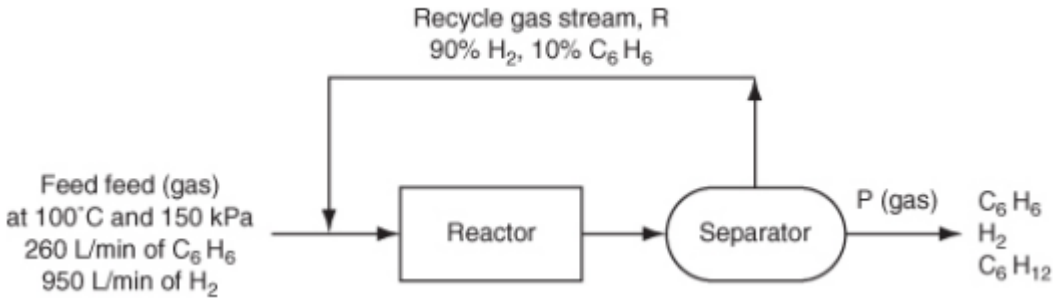
Q. 1 A process involving catalytic dehydrogenation in the presence of hydrogen is known as hydroforming. Toluene, benzene, and other aromatic materials can be economically produced from naphtha feedstocks in this way. After the toluene is separated from the other components, it is condensed and cooled in a process such as the one shown in the Figure below. For every 100 kg of C charged into the system, 27.5 kg of a vapor mixture of toluene and water (9.1% water) enter the condenser and are condensed by the C stream. Calculate
(a) the temperature of the C stream after it leaves the condenser, and
(b) the kilograms of cooling water required per hour [10 M]



Additional data:

Stream	C_p[kJ/(kg)(°C)]	B.P. (°C)	ΔH_{vap}(kJ/kg)
$H_2O(l)$	4.2	100	2260
$H_2O(g)$	2.1	—	—
$C_7H_8(l)$	1.7	111	230
$C_7H_8(g)$	1.3	—	—
C(s)	2.1	—	—

Q.2 Benzene (C_6H_6) is converted to cyclohexane (C_6H_{12}) by direct reaction with H_2. The fresh feed to the process is 260 L/min of C_6H_6 plus 950 L/min of H_2 at 100°C and 150 kPa. The single-pass conversion of H_2 in the reactor is 48% while the overall conversion of H_2 in the process is 75%. The recycle stream contains 90% H_2 and the remainder benzene (no cyclohexane).
(a) Determine the molar flow rates of H_2, C_6H_6 , and C_6H_{12} in the exiting product.
(b) Determine the volumetric flow rates of the components in the product stream if it exits at 100 kPa and 200°C.
(c) Determine the molar flow rate of the recycle stream, and the volumetric flow rate if the recycle stream is at 100°C and 100 kPa. [5× 3 = 15 M]



Q. 3 A gas has the following composition:

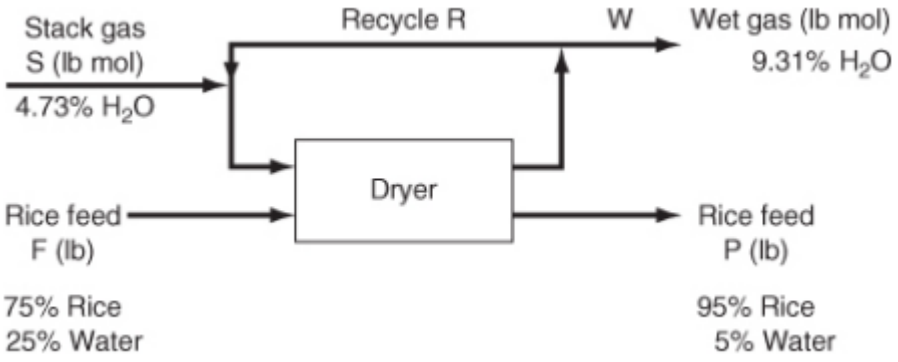
CO_2	10%
CH_4	40%
C_2H_4	50%

It is desired to distribute 33.6 lb of this gas per cylinder. Cylinders are to be designed so that the maximum pressure will not exceed 2400 psig when the temperature is 180°F. Calculate the volume of the cylinder required by Kay's method. [5 M]

Q.4 The pressure gauge on an O_2 cylinder stored outside at 0°F in the winter reads 1375 psia. By weighing the cylinder (whose volume is 6.70 ft^3) you find that the net weight, that is, the O_2, is 63.9 lb. Is the reading on the pressure gauge correct? Use RK equation of state to make your calculations. [5M]

Q.5 (a) The critical temperature of a real gas is known to be 500 K, but its critical pressure is unknown. Given that 3 lb mol of the gas at 252°occupies 50 ft^3 at a pressure of 463 psia, estimate the critical pressure.
(b) You have been asked to settle an argument. The argument concerns the maximum allowable working pressure (MAWP) permitted in an A1 gas cylinder. One of your coworkers says that calculating the pressure in a tank via the ideal gas law is best because it gives a conservative (higher) value of the pressure than can actually occur in the tank. The other coworker says that everyone knows the ideal gas law should not be used to calculate real gas pressures as it gives a lower value than the true pressure. Which coworker is correct? [10 M]

Q.6 To save energy, stack gas from a furnace is used to dry rice. The flowsheet and known data are shown in Figure. 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%?



[15 M]

Q.7 A rotary dryer operating at atmospheric pressure dries 10 tons/day of wet grain at 70°F, from a moisture content of 10% to 1% moisture. The airflow is countercurrent to the flow of grain, enters at 225°F dry-bulb and 110°F wet-bulb temperature, and leaves at 125°F dry-bulb. See Figure P11.3.1. Determine (a) the humidity of the entering and leaving air if the latter is saturated; (b) the water removal in pounds per hour; (c) the daily product output in pounds per day; (d) the heat input to the dryer. Assume that there is no heat loss from the dryer, that the grain is discharged at 110°F, and that its specific heat is 0.18. [20 M]