(3 Hours) **[Total Marks: 80]**

N.B 1. Question number **one** is compulsory.
2. Attempt any three of the remaining questions.
3. Each question carries equal marks.
4. Figures to the right indicate marks.
5. Make suitable assumptions when required.

1 (a) Find the average molar mass of air containing 79% (v/v) N_2 and 21% (v/v) O_2 . Compute the composition of air by mass. **05**

(b) Draw the block diagram of the following unit operations and identify the tie component in the unit operations if any. Distillation, gas absorption and drying. **06**

(c) Define adiabatic flame temperature, heat of combustion and heat of reaction. **06**

(d) Convert 294 g/L H_2SO_4 to normality and molarity **03**

2 (a) A solution of potassium dichromate in water contains 15% (w/w) $K_2Cr_2O_7$. Calculate the amount of $K_2Cr_2O_7$ that can be produced from 1500 kg of this solution, if 700 kg of water is evaporated and remaining solution is cooled to 293 K. Given that the solubility of $K_2Cr_2O_7$ at 293 K is 115kg/1000kg water. **05**

(b) A mixture of phenol and water forms two separate liquid phases, one rich in phenol and other rich in water and the composition of the layers are 70% and 9 %(w/w) phenol respectively. If 500kg of phenol and 700kg of water are mixed and layers allowed to separate, find the individual mass of the layers. **05**

(c) Fresh fruit juice contains 15% solids and rest water. It is desired to concentrate this juice, by evaporation to a solid concentration of 40%. However, to avoid a flat taste of the product, it is not advisable to do direct evaporation of the entire juice. A portion of the fresh juice is bypassed the evaporator and mixed with the evaporated juice containing 55% solids. Thus a juice containing 40% solids is obtained from the process. Calculate the fraction of juice that bypasses the evaporator. All composition is by mass. **10**

3 (a) A combustion reactor is fed with 50kmol/h of butane and 2000kmol/h of air. Calculate the % excess air used and composition of the flue gas if conversion is 100%. **10**

(b) Acetylene is produced as per the reaction: **10**

$$CaC_2 + 2H_2O \rightarrow C_2H_2 \uparrow + Ca(OH)_2$$

If 100L of gas is burnt per hour at 298K and 98.68kPa ,calculate the amount of CaC_2 in kg which must be used in the acetylene lamp, at the above temperature & pressure, to get 15 hours service of the lamp. CaC_2 reacts to give acetylene gas to burn in the lamp.

4 (a) Formaldehyde is produced by dehydrogenation of methanol. The per pass conversion is 67%. The product leaving the reactor is fed to separation unit where formaldehyde is separated from methanol and hydrogen. The separated methanol is recycled to reactor. If the production rate of formaldehyde is 1000kg/h, calculate the combined feed ratio and the flow rate of methanol required to the process as fresh feed. **10**

(b) In production of bean oil,beans containing 10%(w/w) oil and 90%(w/w) solids are ground and fed to the reactor,where they remain suspended in hexane. The feed ratio is 3kg hexane/kg beans.All oil in the beans is extracted into the hexane. This mixer effluent passes to a filter.The filter cake contains 75%(w/w) solids and rest bean oil and hexane.Filter cake is discarded and the the liquid filtrate is send to an evaporator, where hexane is vaporised and thus separating the oil.The hexane vapour is condensed and recycled to the reactor. Calculate the fresh hexane feed per 100kg of beans fed and the recycle to fresh feed ratio. **10**

5 (a) Temperature of oxygen is raised from 350K to 1500K .Calculate the amount of heat that must be applied for raising the temperature of 32kg of oxygen using C_p data provided. $C_p=a+bT+cT^2+dT^3$ **10**

Gas	a	$b\times10^3$	$c\times10^6$	$d\times10^9$
O_2	26.0257	11.7551	-2.3426	-0.5623

(b) A natural gas has the following composition on mole basis: **10**
CH_4=84%,C_2H_6=13% and N_2=3%.Calculate the heat to be added to heat 200kg of natural gas from 311K to 533K.C_{pm} values in kJ/(kmol K).

Gas	C_{pm} (311-298 K)	C_{pm} (533-298 K)
CH_4	36.0483	41.7800
C_2H_6	53.5240	67.4954
N_2	29.1317	29.5378

6 (a) Obtain an empirical equation for calculating the heat of reaction at any temperature T K for the reaction: **10**

$$CO_{(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(g)}$$

Data : ΔH_R^0 = -90.41 kJ/mol

Component (gas)	a	$b\times10^3$	$c\times10^6$	$d\times10^9$
CO	29.0277	-2.8165	11.6437	-4.7063
H_2	28.6105	1.0194	-0.1476	0.769
CH_3OH	21.137	70.843	25.86	-28.497

(b) Give the step wise procedure to calculate the reboiler load in a distillation unit. List the parameters required for the computation of the above. **10**
