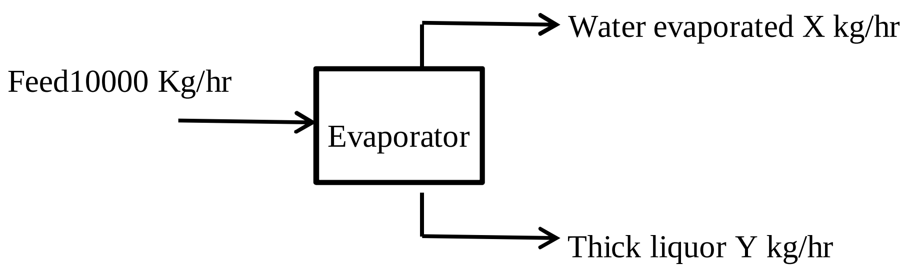
SUMMER-14 EXAMINATION
Model Answer

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

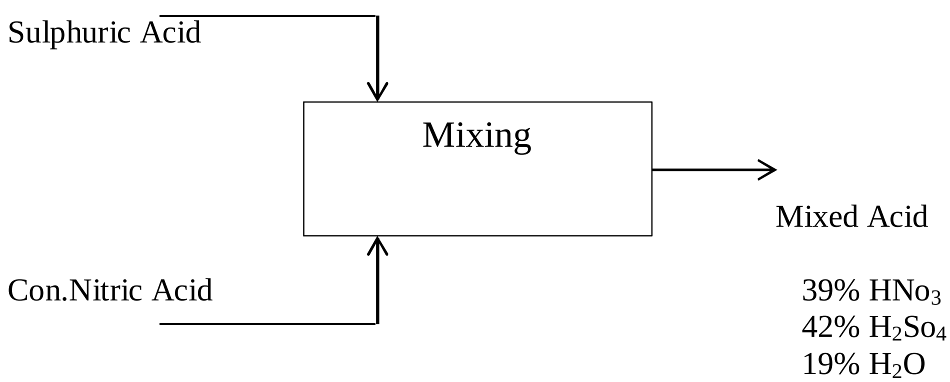
Q No.	Answer	marks	Total marks
1a-i	Conditions for **NTP:** Temperature(T)=273 K(0^oC), Pressure(P)=101.325 KPa(1 atm), moles(n)=1kmol, Volume(V)= 22.4 m^3 **STP:** Temperature(T)=300K(27^oC), Pressure(P)=101.325KPa (1 atm), moles(n)=1kmol, Volume(V)= 22.4 m^3	 1 1	 2
1a-ii	$CO+2H_2 \text{-----}\rightarrow CH_3OH$ Stoichiometric coefficient of $CO:H_2$ = 1:2 Weight ratio of $CO:H_2$ = 28:4 or 7	 1 1	2
1a-iii	**Dalton's law:** It states that the total pressure exerted by a gas mixture is equal to the sum of partial pressures **Mathematical Statement**:$P = P_1+P_2+P_3$ where P is the total pressure of gas mixture , P_1,P_2,P_3 are partial pressures	1 1	2
1a-iv	**Raoult's law:**It states that at a given temperature, the equilibrium partial pressure of a component of a solution in the vapour is equal to the product of the mole fraction of the component in the liquid phase and the vapour pressure of the pure component. **Henry's law:**It states that the partial pressure of the solute gas in gas phase is directly proportional to the mole fraction of a solute gas dissolved in a liquid equilibrium above the liquid surface.	1 1	2
1a-v	**Application of Hess's law:** Using this law we can calculate the heat of	2	2

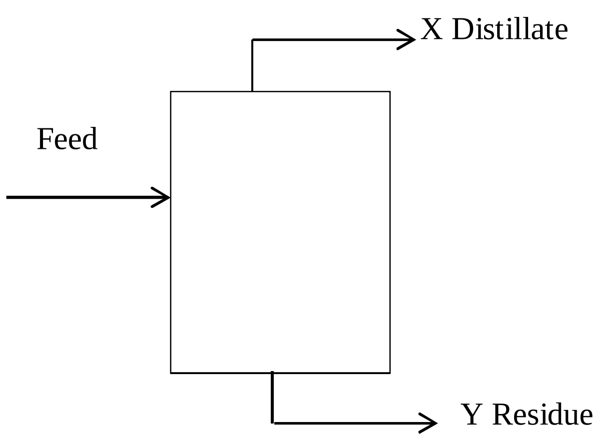
	formation of a compound from a series of reactions that do not involve the direct formation of the compound from its elements.		
1a-vi	**Conversion**:It is the ratio of amount of limiting reactant reacted to the amount of limiting reactant fed to the reactor. **%Yield of desired product =** (moles of limiting component reacted to form desired product/ total moles of limiting component reacted)* 100	1 1	2
1b-i	**Basis:** Average molecular weight of gas mixture=22.4 Let X_A& X_B be the mole fractions of CH_4 & C_2H_4 respectively $M_{av}=M_AX_A+M_BX_B$ $22.4= 16X_A+28X_B$ ……….(1) $1= X_A+X_B$ ……………(2) Solving (1) &(2) we get $X_A= 0.467$ and $X_B=0.533$ **Mole fraction of CH_4 =0.467& Mole fraction of C_2H_4=0.533**	1 1 1 1 2	6
1b-ii	Henry's law is $p_A= H X_A$ $25.33 = 4.46*10^6 X_A$ Or $X_A = 5.68*10^{-6}$ i.e mole fraction of $O_2 = 5.68*10^{-6}$ mole fraction of O_2 = moles of O_2/ (moles of O_2 + moles of solvent) If the solution is very dilute mole fraction of O_2 = moles of O_2/ (moles of solvent) $5.68*10^{-6} = 5.68*10^{-6}/ 1$ **Solubility of O_2 = $5.68*10^{-6}$**	1 1 1 1 1 1	6

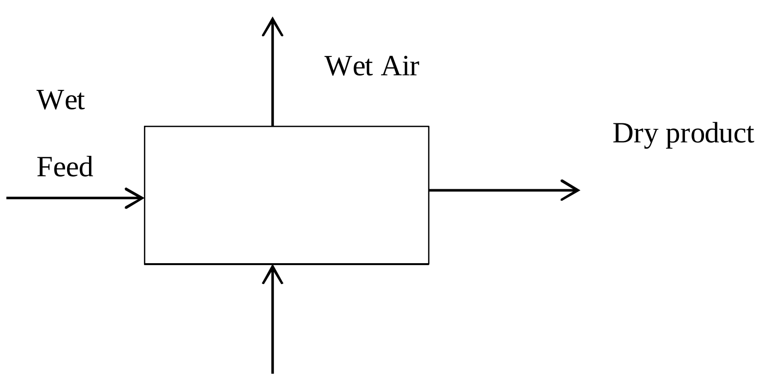
1b-iii	Basis:Gas in a closed vessel at 299 K $P_1V_1/T_1 = P_2V_2/T_2$ P_1=121.59 KPa g = 121.59 + 101.325 = 222.915 KPa absolute $V_1 = V_2$ T_1 =299 K P_2=? T_2 = 1273 K 222.915/299 = P_2/ 1273 P_2 = 949.07 KPa	1 1 1 1 2	6
2-a	Basis: 10000 Kg/hr of weak liquor  Overall balance is 10000= X+Y Individual balance for caustic is 15/100 *10000 = 40/100 * Y Y= 3750 & X= 6250 Kg/hr of water evaporated = 6250 Kg/hr Kg/hr of thick liquor obtained = 3750 Kg/hr	1 1 2	4
2-b	**Recycling:** It is returning back a portion of stream leaving a process unit to the entrance of the process unit for further processing. **Reasons for performing recycling: (**any four) 1. Maximum utilization of the valuable reactant 2. Improvement of the performance of the equipment/ operation	1 ¾ marks each for any 4	4

	3. Utilisation of the heat being lost in the exit stream. 4. Better operating conditions of the system 5. Improvement in the selectivity of a product 6. Enrichment of a poduct		
2-c	**Excess component:** It is the reactant which is in excess of the theoretical or stoichiometric requirement.	1.5	4
	Limiting component: It is the reactant which would disappear first if a rection goes to completion.Or it is the reactant which decides the extent of a reaction.	1.5	
	Example: In the reaction C_2H_4 + ½ O_2 ----→ C_2H_4O, oxygen(air) is fed to the reactor in excess of that theoretically required. Therefore Oxygen is the excess component and ethylene is the limiting component.	1	
2-d	**Basis:** 33.33kmol of formaldehyde produced. CH_3OH -----→ HCHO + H_2 I kmol CH_3OH reacted = 1kmol HCHO formed	1	4
	CH_3OH reacted to produce 33.33 kmol HCHO = 33.33 kmol Conversion of CH_3OH =(kmole of CH_3OH reacted/ kmoles	1	
	Of CH_3OH fed)*100 65 =(33.33/kmole of CH_3OH fed)*100 kmole of CH_3OH fed = 51.28 kmoles/hr	1	
	kg of CH_3OH fed = 51.28* 32=**1641Kg/hr**	1	
2-e	**Basis:** 50 kmoles /hr butane C_4H_{10} + 6.5 O_2 -----→ 4CO_2 + 5 H_2O 100 kmol air fed = 21 kmol O_2 fed 2100 kmol air fed = ?	1	4
	O_2 fed = 2100*21/100= 441kmoles 1 kmol C_4H_{10} fed = 6.5 kmol O_2 theoretically required 50 kmol C_4H_{10} fed = ?	1	

	O_2 theoretically required = 325 kmol % excess= (O_2 fed-O_2 theoretical)*100/ O_2 theoretical = (441-325)*100/325 = **35.69%**	1 1	
2-f	**Specific Heat:** Specific heat of a substance is the ratio of the heat capacity substance to that of water. **Latent Heat:**It is the heat required to change the phase of a substance at constant temperature and pressure. **Unit of heat in S.I.**is Kilojoules(KJ)	1.5 1.5 1	4
3-a	Basis 100 mol of ethylene Reaction I $C_2H_4 + \frac{1}{2}O_2 \longrightarrow C_2H_4O$ Reaction II $C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$ From reaction I 1Kmol of C_2H_4O formed≡ 1Kmol C_2H_4 reacted ∴ C_2H_4O reacted to from 80 kmol C_2H_4O $= \frac{1}{1} \times 80$ = 80Kmol From reaction II 2kmol of CO_2 formed ≡ 1Kmol C_2H_4 reacted ∴C_2H_4 reacted to form 10 kmol CO_2 $= \frac{1}{2} \times 10$ = 5Kmol ∴C_2H_4 totally reacted = 80 + 5= 85 ∴% conversion of $C_2H_4 = \frac{85}{100} \times 100$ = 85% % yield of $C_2H_4O = \frac{80}{85} \times 100$ = 94.12%	1 1 2 2 1 1	8

3-b	.Basis – 100kg of mixed acid  Acl ‘x’ kg of nitric acid & ‘y’ kg of H_2SO_4 68.3 $\therefore$ Overall balance x+ y = 100 Material balance of Nitric acid 0.683x = 39 $\therefore x = \frac{39}{0.683}$ Weight of HNO_3 = 57.1 $\therefore$ Weight of H_2SO_4 = 100 – 57.1 = 42.9 kg Strength of H_2So_4 0.429y = 42 $\therefore y = \frac{42}{0.429}$ = 97.9 Weigth ratio of $HNo_3 = \frac{\text{Kg of } HNO_3}{\text{Kg of } H_2So_4}$	1 1 1 1 1 1	8

	$= \frac{57.1}{42.9}$ $= 1.33$	2	
3-c	 Basis 5000kg of feed. xF = 50% xD = 95% xW= 8% Weight of Benzene in feed = 5000 ×0. 5 = 2500kg Overall balance x + y = 5000 Material balance of benzene 0.95x + 0.08y = 5000 × .5 .95x + 0.08y = 2500	1 1 1 1	8

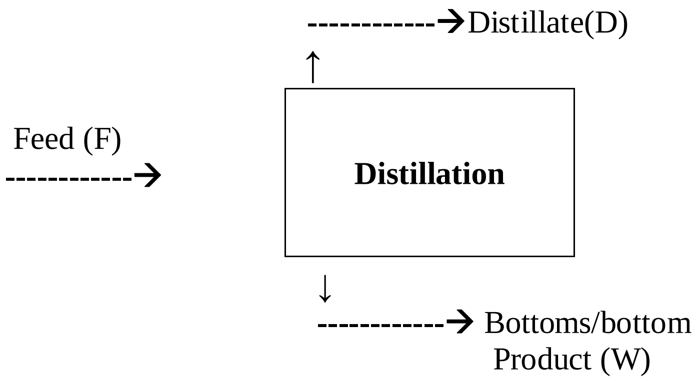
	Solving for x & y x = 2413.79 kg y = 2586.21 kg % Recovery of Benzene $= \frac{2293.10}{2500} \times 100$ = 91.72%	2 2	
4-a	Basis 1mol of n propanol liquid 1) C (s) + O_2 (g) = CO_2 (g) $\Delta H_1 = -393.51 \frac{K5}{md}$ 2) H_2 (g) + $\frac{1}{2}$ O_2 (g) = H_2O (e) $\Delta H_2 = -285.83 \frac{K5}{md}$ 3) C_3H_7OH (^{l}) + $4.5O_2$ = $3CO_2$ + $4H_2O$ $\Delta Hc = -2028.19$ ΔH_+ C_3H_7OH = Heat of formation of n propanol $= 3\Delta H_1 + 4\Delta H_2 - \Delta H^0C$ = 3 (-39351) + 4 (-285.83) – (-2028.19) = - 295.66 kJ/mol.	2 2 2 2	8
4-b	Basis = 2000Kg/hr of lumber  	1	8

	Weight of moisture in lumber = 2000 × 0.05 = 100Kg $\therefore$ Weight of dry lumber = 2000 – 100 = 1900Kg Let weight of dry air supplied = xkg $\therefore$ Material balance of moisture 0.02x = 100 $\therefore x = \frac{100}{0.02}$ = 5000kg/hr Weight of dry air = 5000Kg/hr	2 1 2 2	
4-c	Basis – 50Kmol SO_2 150 Kmol air Reaction $SO_2 + \frac{1}{2}O_2 = SO_3$ Air used = 150Kmol O_2 in air = 150 × (0.21) = 31.5 Kmol Theorctical requirement of O_2 1 Kmol $SO_2 \equiv 0.5$ Kmol O_2 $= \frac{0.5}{1} \times 50$ = 25 Kmol $\therefore$% excess of O_2 used	2 2 2	8

	$= \frac{O_2 \text{ in supplied} - O_2 \text{ theo read}}{O_2 \text{theo read}}$ $= \frac{31.5-25}{25} \times 100$ = 26 $\therefore$ % excess air used = 26% Or Theo.air read = $\frac{100}{21} \times 25$ = 119.05 Kmol $\therefore$% excess air used = $\frac{150-119.05}{119.05}$ = 26%	2	
5-a	**Basis:** 100 kmol of flue gas. It contains 13.4 kmol CO_2,80.5 kmol N_2 and 6.1 kmol O_2 N_2 in supplied air = N_2 in flue gas = 80.5 kmol Air contains 79% N_2 by volume. Amount of air supplied = 80.5/ 0.79 = 101.9 kmol Amount of O_2 in supplied air = 0.21X101.9=21.4 kmol Amount of O_2 in flue gas = 6.1 kmol Amount of O_2 consumed in combustion of fuel = 21.4 - 6.1 = 15.3 kmol % excess air = % excess O_2 Present excess air supplied = (21.4 – 15.3)/ 15.3 X 100 **= 39.9 % ------ Ans.**	1 1 1 1 1 1 1 1	8
5-b	**Case –I: Basis:** 100 Kg/hr of solid handling capacity of the evaporator.	1	8

	--------→ Water evaporated		
	↑		
	Weak liquor ------------→ 5% solids **Evaporator**		
	↓		
	-------→ Thick liquor,50% solids		
	Let X be the be the Kg/hr of weak liquor then we have.	1	
	$0.05 X = 100$		
	$X = 2000$ Kg/hr		
	Y be the Kg/hr of thick liquor then we have.		
	$0.5 Y = 100$	1	
	$Y = 200$ kg/hr		
	Overall Material Balance:		
	Kg/hr of weak liquor = Kg/hr of thick liquor + Kg/hr of Water evaporated	1	
	2000 = 200 + Kg/hr of Water evaporated		
	Kg/hr of Water evaporated = 1800 Kg/hr	1	
	Case –II: Basis: 1800 Kg/hr of Water evaporated		
	Let A be the be the Kg/hr of weak liquor		
	B be the be the Kg/hr of thick liquor		
	Overall Material Balance:		
	$A = B + 1800$		
	Material Balance of Solids :		
	$0.04 A = 0.35 B$		
	$A = 8.75 B$		
	Putting in above equation	2	
	$8.75 B = B + 1800$		

	B = 232.26 Kg/hr A = 232.26 + 1800 = 2032.26 Kg/hr Solid in weak liquor = 0.04 X 2032.26 = 81.3 Kg/hr Solid handling Capacity = 81.3 Kg/hr ------- **Ans.**	2	
5-c	**Basis:** 1 mol of gaseous ethanol reacted $C_2H_5OH(g) \text{----------}\rightarrow CH_3CHO(g) + H_2(g)$ ΔH^o_R = Standard heat of reaction $= [\Sigma \Delta H^o_c]$ reactant - $[\Sigma \Delta H^o_c]$ product $= [1 \times \Delta H^o_c\ C_2H_5OH(g)] - [1 \times \Delta H^o_c\ CH_3CHO(g) + 1 \times \Delta H^o_c\ H_2]$ = [1 x -1410.09)] – [1 x (-1192.65) + 1 x (-285.83)] = -1410.09 + 1478.48 **= 68.39 KJ ----- Ans.**	1 2 3 2	8
6-a	Reaction given $CH_4 + 10\ O_2 \text{------}\rightarrow CO_2 + 2H_2O$ Balanced Reaction is, $CH_4 + 2\ O_2 \text{------}\rightarrow CO_2 + 2H_2O$ From balanced reaction, 1 kmol CH_4 required ≡ 2 kmol O_2(theoretically required) Actual kmol of O_2 charged = 10 kmol **Hence, Excess component is O_2 ------ Ans.**	1 1 1 1	4

6-b	**DISTILLATION:** This operation used for the separation of components of a liquid.  **Overall Material Balance:** Feed = Distillate + Bottoms/ Bottom Product $F = D + W$ F= Feed in Kg/hr , D= Distillate in Kg/hr, W = Bottom Product Kg/hr	2 2	4
6-c	**Basis :** 100 Kg of ground nut seeds Let X be the Kg of cake obtained **Material balance of Solids :** Solids in seeds = Solids in cake $0.45 * 100 = 0.8 * X$ $X = 56.25$ Kg **Material balance of Oil :** Oil in seeds = Oil in cake + Oil recovered $0.45 * 100 = 0.05 * 56.25 +$ Oil recovered Oil recovered $= 45 - 2.81 = 42.19$ Kg % recovery of Oil $= \dfrac{\text{Oil recovered}}{\text{Oil in Seeds}} * 100$	1 1 1	4

	% recovery of Oil = $\frac{42.19}{45}$ * 100 **% recovery of Oil = 93.75% ----------- ans.**	1	
6-d	**Basis:** 1 Kg of petrol Amount of H2 in petrol = 0.15 kg, Amount of C in petrol= 0.85 Kg $H_2 + 0.5\ O_2 \text{ -----}\rightarrow H_2O$ $C + O_2 \text{ -----}\rightarrow CO_2$ From reaction, 1 kmol H_2 ≡ 0.5 kmol O_2 2 kg H_2 ≡ 16 kg O_2 1 katom C ≡ 1 kmol O_2 12 kg C ≡ 32 kg O_2 Theoretical requirement of O_2 for H_2 = 0.15 x (16/2) = 1.20 kg Theoretical requirement of O_2 for C = 0.85 x (32/12) = 2.27 kg Total Theoretical requirement of O_2 =1.20 +2.27 = 3.47 kg **Amount of air required for combustion = 3.47/0.23** **=15.09 kg ------Ans.** (Air contain 23 % O_2 and 77 % N_2 on weight basis) Amount of air required supplied = 15 x1.15 =17.35 Kg N_2 in supplied air = (0.77 x 17.35)/28 = 0.477 kmol O_2 in supplied air = (0.23 x 17.35)/32 = 0.125 kmol	1 1 1	4

<table>
<tr><td></td><td>
O_2 in dry product = 0.23(17.35-15)/32 = 0.016 kmol

We have
1 katom C ≡ 1 kmol CO_2

(0.85/12) katom C ≡?

CO_2 produced = 1/1 X (0.85/12) = 0.071 kmol

The product flue gases contain CO_2, O_2, N_2

For ideal gases, Volume % = Mole %

Composition Of Dry Product Gases on vol%:

<table>
<tr><th>Component</th><th>Quantity ,Kmol</th><th>Mole %(vol%)</th></tr>
<tr><td>CO_2</td><td>0.071</td><td>12.6</td></tr>
<tr><td>O_2</td><td>0.016</td><td>2.8</td></tr>
<tr><td>N_2</td><td>0.477</td><td>84.6</td></tr>
<tr><td>Total</td><td>0.564</td><td>100.00</td></tr>
</table>
</td><td>1</td><td></td></tr>
<tr><td>6-e</td><td>
Basis : 100 kmol of SO_2 entering the reactor

Reaction:

$SO_2 + ½ O_2$ ---→ SO_3

From reaction,

1 kmol SO_2 ≡ 1 kmol SO_3

i.e 1 kmol SO_3 requires l kmol SO_2 to be reacted

1 kmol SO_3 ≡ 1 kmol SO_2

80 kmol SO_3 ≡ ?
</td><td>1</td><td>4</td></tr>
</table>

	SO_2 reacted = 80 x (1/1) = 80 kmol % conversion of SO_2 = $\frac{\text{kmol } SO_2 \text{ reacted}}{\text{kmol } SO_2 \text{ charged}}$ X 100 = $\frac{80}{100}$ X 100 = 80 % **% conversion of SO_2 = 80 % ----------- Ans.**	1 1 1	
6-f	**Sensible Heat :** Sensible heat is the heat that must be transferred to raise or lower the temperature of a substance or mixture of substance. **Adiabatic Reaction:** It is the reaction which proceeds without loss or gain of heat, When the adiabatic reaction is exothermic, the temperature of the product stream rise and when the adiabatic reaction is endothermic, the temperatures of the product stream decreases	2 2	4