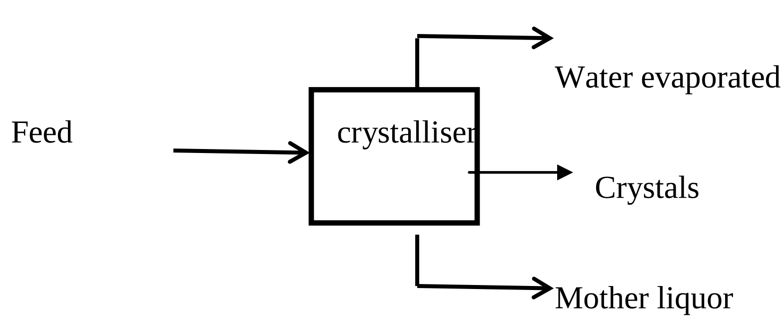
SUMMER-17 EXAMINATION

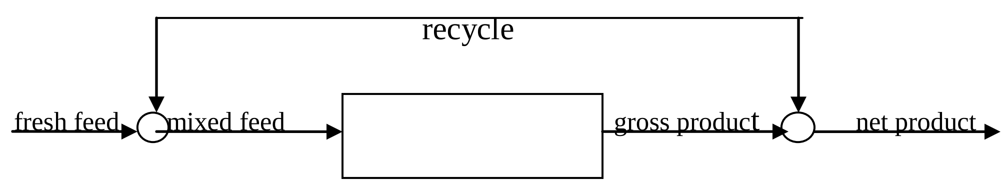
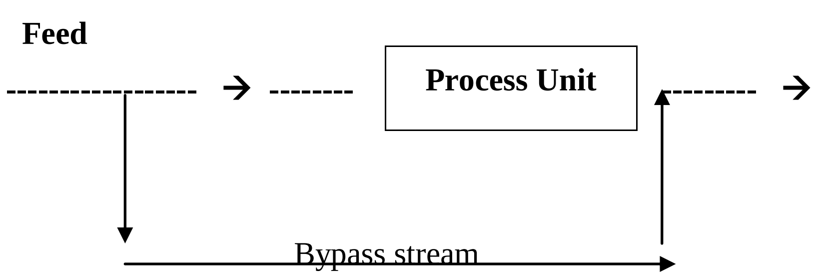
Model Answer

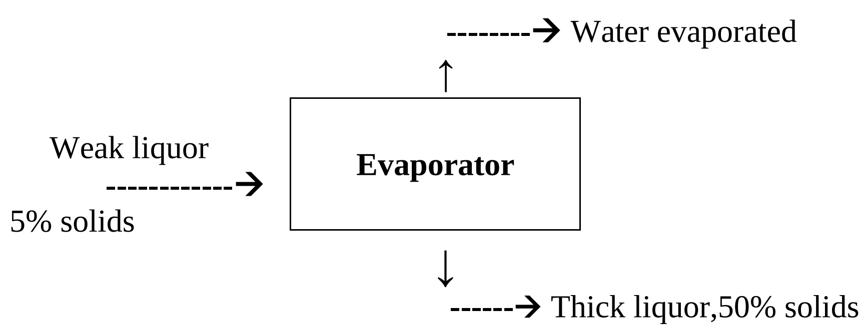
Important Instructions to examiners:

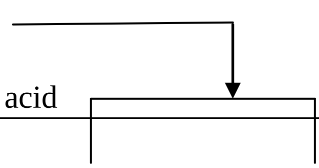
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.

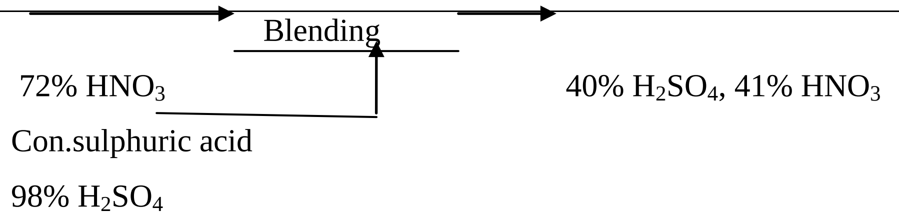
Q No.	Answer	marks
1	Any 10	20
1-a	**Ideal Gas law:** PV=nRT where P - pressure, V - volume, n- moles, K-absolute temperature and R – universal gas constant.	1 1
1-b	**Vander Waal's equation of state:** $(P+a/V^2)(V-b)= nRT$ Where a & b are constants	2
1-c	**% Conversion:** It is the ratio of amount of limiting reactant reacted to the amount of limiting reactant totally charged. Express in percentage.	2
1-d	**Excess component:** It is the reactant which is in excess of the theoretical or stoichiometric requirement. ORIt is the component which decides the extend of a reaction.	2
1-e	**Sensible Heat :** Sensible heat is the heat that must be transferred to raise or lower the temperature of a substance or mixture of substance. **Latent Heat :** When matter undergoes a phase change, the enthalpy change associated with unit amount of matter at constant temperature and pressure is known as Latent Heat of phase change.	1 1
1-f	**Material balance diagram for crystallisation** 	2

1-g	**Standard heat of combustion:** It is the amount of heat liberated when one mol of a compound is combusted or burned in oxygen at standard conditions.(25^0C and 1atm pressure)	2
1-h	**Heat capacity at constant volume:** It is the amount of heat required to increase the temperature of one gram of substance by one degree.(under constant volume)	2
1-i	**Raoult's law:**It states that at a given temperature, the equilibrium partial pressure of a component of a solution in the vapour phase is equal to the product of the mole fraction of the component in the liquid phase and the vapour pressure of the pure component. $p_A = p^0_A X_A$ p_A- partial pressure p^0_A - vapour pressure vapour X_A - mole fraction of the component in the liquid phase	1 1
1-j	**Law of conservation of energy:** Energy input= energy output + accumulation	2
1-k	**1)Stoichiometric Equation :** The stoichiometric equation of a chemical reaction is the statement indicating relative moles of reactant and products that take part in the reaction. **2) Stoichiometric ratio :** it is the ratio of stoichiometric coefficient of two molecular species or Components in the balanced reaction	1 1
1-l	**Dalton's law:** It states that the total pressure exerted by a gas mixture is equal to the sum of partial pressures	1

	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
2	Any 2	16
2-a	**Recycling:** It is returning back a portion of stream leaving a process unit to the entrance of the process unit for further processing  Recycling is used for maximum utilisation of the valuable reactants, improvement of the performance of the operation, utilization of the heat being lost in the exit stream, improvement in the selectivity of the products, maintaining process rate at a high value and enrichment of a product. **Bypass Operation :** In these operations, a fraction of the feed stream to a process unit is diverted around and combined with the output stream.  - Bypassing is practiced industrially whenever accurate control of the	2 2 2 2

	composition or concentration of the process exit stream is expected.	
	- The composition and properties of the product may be varied by varying the fraction of the feed that is bypassed.	
	Example: A juice concentration process in which the dehydration process runs most efficiently by removing more water than is desired. A portion of the feed may be directed around the dehydrator in a bypass loop, to be mixed with unprocessed feed. **Or** any other example	
2-b	Basis: 100 kmol air	
	Avg. mol.wt of air = $M_1X_1+M_2X_2$	2
	= 28 * 0.79 + 32 * 0.21	
	= **28.84**	2
	Density = P* Mav / RT	2
	= 101.325 * 28.84/ 8.314 * 273	2
	= **1.287 Kg/m^3**	
2-c	**Case –I: Basis:** 100 Kg/hr of solid handling capacity of the evaporator.	
		1
	Let X be the be the Kg/hr of weak liquor then we have.	
	0.05 X = 100	
	X = 2000 Kg/hr	1
	Y be the be the Kg/hr of thick liquor then we have.	
	0.5 Y = 100	

	Y = 200 kg/hr	1
	Overall Material Balance:	
	Kg/hr of weak liquor = Kg/hr of thick liquor + Kg/hr of Water evaporated	
	2000 = 200 + Kg/hr of Water evaporated	1
	Kg/hr of Water evaporated = 1800 Kg/hr	
	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	1
	Material Balance of Solids :	
	0.06 A = 0.36 B	
	A = 6 B	
	Putting in above equation	
	6 B = B + 1800	1
	B = 360 Kg/hr	
	A = 360 + 1800 = 2160 Kg/hr	1
	Solid in weak liquor = 0.06 X 2160 = 129.6 Kg/hr	
	Solid handling Capacity = **129.6 Kg/hr** ------- **Ans.**	1
3	Any 2	16
3-a	**SOLUTION :**	
	BASIS : 1000 kg of desired mixed acid.	1
	Waste acid, 28 % H_2SO_4,35% HNO_3	
		1
	 Desired mixed acid	
	Con.nitric acid 1000 kg	



	Block diagram for fortifying waste acid with concentrated acids	
	Let x, y and z be the kg of waste acid , concentrated sulphuric acid and concentrated nitric acid required to make 1000 kg desired acid.	
	Overall material Balance:	
	$x + y + z = 1000$…..(i)	1
	Material Balance of H_2SO_4 :	
	$0.28\ x + 0.98\ y = 0.4 \times 1000$….(ii)	1
	$0.28\ x + 0.98\ y = 400$	
	Material Balance of HNO_3 :	
	$0.35\ x + 0.72\ z = 0.41 \times 1000$	
	$0.35\ x + 0.72\ z = 410$…..(iii)	1
	Solving the above three equations, we get	
	X= 98.14	
	Y= 380.12	
	Z= 521.74	
	Amount of waste acid required = 98.14kg	3
	Amount of concentrated sulphuric acid required = 380.12 kg	
	Amount of concentrated nitric acid require = 521.74 kg ….Ans	
3-b	**Basis:** 50 kmoles /hr butane	

	C_4H_{10} + 6.5 O_2 -----→ 4CO_2 + 5 H_2O	1
	100 kmol air fed = 21 kmol O_2 fed	
	2100 kmol air fed = ?	
	O_2 fed = 2100*21/100= 441 kmoles	2
	1 kmol C_4H_{10} fed = 6.5 kmol O_2 theoretically required	
	50 kmol C_4H_{10} fed = ?	
	O_2 theoretically required = 325 kmol	2
	% excess= (O_2 fed-O_2 theoretical)*100/ O_2 theoretical	1
	= (441-325)*100/325	
	= **35.69%**	2
3-c	**Steps involved in solving material balance calculations:** 1.Assume suitable basis of calculation as given in problem. 2. Adopt weight units in case of problem of process without chemical reaction. 3. Draw block diagram of process 4. Show input and output streams 5. Write overall material balance 6. Write individual material balance 7. Solve above two algebraic equations 8. Get values of two unknown quantities. 9.Write balances as follows:	1 mark each

	feed	product	Component removed
Unchanging component			
Outgoing			

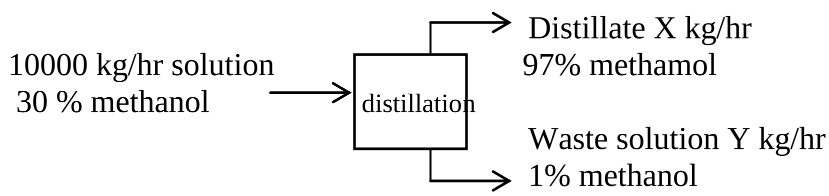
	component	
4	Any 2	16
4-a	$C_2H_4 + ½ O_2 \longrightarrow C_2H_4O$ $C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$ Basis : 100 kmol ethylene and 100 kmol O_2 fed Conversion of ethylene = 85% Conversion of ethylene = (kmol ethylene reacted / kmol ethylene fed) * 100 85 = (kmol ethylene reacted / 100) * 100 kmol ethylene reacted = 85 % yield of C_2H_4O = (kmol C_2H_4 reacted to form C_2H_4O/total C_2H_4 reacted) * 100 94.12 = (kmol C_2H_4 reacted to form C_2H_4O/85) * 100 kmol C_2H_4 reacted to form C_2H_4O = 80kmol kmol C_2H_4 reacted for 2nd reaction = 85 – 80 = 5 kmol CO_2 formed = 2 * 5 = **10 kmol** H_2O formed = 2 * 5 = **10 kmol** O_2 reacted = (80 * 0.5 + 3 * 5) = 55 kmol O_2 unreacted = (100 – 55) = **45 kmol** C_2H_4 unreacted = (100 – 85) = **15 kmol**	1 1 1 1 1 1

Component	Kmol	Mole %
C_2H_4	15	9.38
C_2H_4O	80	50
O_2	45	28.12
CO_2	10	6.25
H_2O	10	6.25

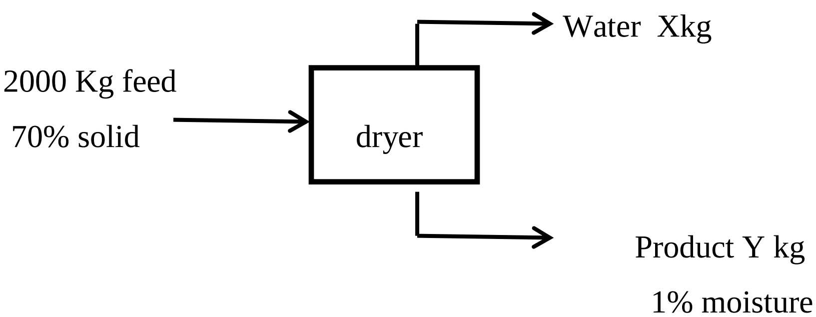
(2 marks)

4-b	**Basis :** 15000 mol/h of N_2- H_2 mixture	

	Molal flow rate of gas mixture = 5 kmol/h $X_{N_2} = 25/100 = 0.25$ $X_{H_2} = 75/100 = 0.75$	1
	$C_P^o \text{ mix} = \Sigma C_P^o \text{ mix} . X_i = X_{N_2} . C_P^o{}_{N_2} + X_{H_2} . C_P^o{}_{H_2}$ $= 0.25 (29.5909 - 5.141 \times 10^{-3} T + 13.1829 \times 10^{-6} T^2 - 4.968 \times 10^{-9} T^3)$ $+ 0.75 (28.6105 + 1.0194 \times 10^{-3} T - 0.1476 \times 10^{-6} T^2 + 0.769 \times 10^{-9} T^3)$ $= 28.8556 - 0.5207 \times 10^{-3} T + 3.185 \times 10^{-6} T^2 - 0.6652 \times 10^{-9} T^3$	2
	Q = Heat added $Q = n \int_{T_1}^{T_2} C^o p \text{ mix } dT$	1
	$Q = n \int_{T_1}^{T_2} [28.8556 - 0.5207 \times 10^{-3} T + 3.185 \times 10^{-6} T^2 - 0.6652 \times 10^{-9} T^3] dT$ $= n [28.8556 (T_2 - T_1) - \frac{0.5207 \times 10^{-3}}{2} (T_2^2 - T_1^2) + \frac{3.185 \times 10^{-6}}{3} (T_2^3 - T_1^3) - \frac{0.6652 \times 10^{-9}}{4} (T_2^4 - T_1^4)]$	2
	Where , n= 15 Kmol/h , T_2 = 473 K , T_1 = 298 K $= 15 [28.8556 (473 - 298) - \frac{0.5207 \times 10^{-3}}{2} (473^2 - 298^2)$ $\quad 3.185 \times 10^{-6} \qquad 0.6652 \times 10^{-9}$	

	$+ \frac{-----------------}{3} (473^{3} - 298^{3}) - \frac{----------------}{4} (473^{4} - 298^{4})]$ Q = 15(5049.73 -35.13 – 7.01) **Q = 76377.6 KJ/h = 21.216 kJ/s = 21.216 kW ------- ans**	 2
4-c	Basis: 1 mol liquid C_5H_{12} $\Delta H^0_R = \Sigma \Delta H^0_{f(pr)} - \Sigma \Delta H^0_{f(react)}$ = [(-393.51*5)+(-285.83*6)]– (-173.49) = **-3509.04KJ**	1 2 2 3
5	Any 2	16
5-a	Basis: 10000 kg/hr of feed  Overall balance is 10000 =X+ Y……………(1) Individual balance for CH_3OH is 0.3*10000 = 0.97X+0.01*Y…………..(2) Solving the equations X**= 3020.83 Kg/hr** **Y= 6979.17 kg/hr** CH_3OH in bottom product = 0.01*6979.17 = 69.79Kg/hr % loss of CH_3OH=(CH_3OH in bottom product/ CH_3OH in feed)*100 = (69.79/3000)*100 = **2.32%**	1 1 1 2 1 1 1
5-b	Henry's law is $p_A = H X_A$	1

	$25.33 = 4.46*10^{6}\ X_A$	1
	Or $X_A = 5.68*10^{-6}$	2
	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)	1
	If the solution is very dilute	1
	mole fraction of O_2 = moles of O_2/ (moles of solvent)	
	$5.68*10^{-6} = 5.68*10^{-6}/ 1$	1
	Solubility of $O_2 = 5.68*10^{-6}$	1
5-c	**BASIS :** 100 mol of ethylene	1
	Reaction I	
	$C_2H_4 + ½\ O_2 \longrightarrow C_2H_4O$	1
	Reaction II	
	C2H4 + 3O2 ⟶ 2CO2 + 2H2O	1
	From reaction I,	
	1Kmol of C2H4O formed = 1Kmol C2H4 reacted	
	∴ C2H4 reacted to form 80 kmol C2H4O	
	$= \frac{1}{1}$ x 80 = 80Kmol	1
	From reaction II,	
	2kmol of CO2 formed = 1Kmol C2H4 reacted	
	∴ C2H4 reacted to form 10 kmol CO2	
	$= \frac{1}{2}$ x10 = 5Kmol	1
	∴ C2H4 totally reacted = 80 + 5= 85	
	∴ % conversion of C2H4 = $\frac{85}{100}$ x 100	1
	= **85%**	
	% yield of C2H4O = $\frac{80}{85}$ x100	1

	= **94.12%**	1
6	**Any 4**	16
6-a	Basis: 2000 kg wet solid  Overall balance is 2000 = X+ Y Balance for solid 0.70 * 2000 = 0.99 * Y Y = 1414.14 kg X = 585.86 Water removed = **585.86 kg** Product obtained = **1414.14 kg**	1 1 1 1
6-b	$CO + 2H_2$ ---------→ CH_3OH a) Stoichiometric ratio of H_2 to CO = 2:1 b) Kmoles of CH_3OH produced per kmol CO reacted = 1 c) Weight ratio of CO to H_2 = 28:4 =7 d) Quantity of CO required to produce 1000 kg CH_3OH = 1000/32 * 28 = **875 kg**	 1 1 1 1
6-c	**General Material Balance Procedure**	4

	1) Assume Suitable Basis of calculation. 2) Adopt weight basis for without chemical reactions and molar basis for with chemical reactions. 3) In case of material balance with chemical, write balance chemical reaction and search out limiting component. 4) In with chemical reaction, the quantity of a reacting component appearing in the product stream is the quantity of that material remains unreacted. 5) Supplied quantity of an excess reactant calculated from the theoretical requirement is based on the quantity of a limiting reactant fed.	
6-d	**Hess's law:** It states that the heat involved in a chemical reaction is same whether the reaction takes place in a single or in several steps. $A \longrightarrow B \quad \Delta T1$ $B \longrightarrow C \quad \Delta T2$ $C \longrightarrow D \quad \Delta T3$ $A \longrightarrow D \quad \Delta T$ Then $\Delta T = \Delta T1 + \Delta T2 + \Delta T3$ **Application of Hess's law:** Using this law we can calculate the heat of formation of a compound from a series of reactions that do not involve the direct formation of the compound from its elements.	2 2
6-e	Basis: $1m^3$ fixed mass of gas at constant temperature P_1 =1atm V_1= 1 m^3 T_1= T= T_2 P_2 =? V_2= 0.5 m^3 $P_1V_1/T_1 = P_2V_2/T_2$ 1*1/T = P2*0.5/T Or P_2= **2 atm**	 1 1 1

	Increase in pressure = (2-1/1) *100 = **100 %**	1
6-f	Basis : 100 kmol product stream Reaction is 2A + B ----→ C Kmol of inerts in product stream = 19.23 kmol Kmol of A in product stream = 23.08 kmol (unreacted) Kmol of B in product stream = 11.54 kmol (unreacted) Kmol of C in product stream = 46.15 kmol (product) Kmol of A reacted (from reaction) 2 * 46.15 = 92.3 Kmol of A fed = Kmol of A reacted + Kmol of A unreacted = 92.3 + 23.08 = 115.38 kmol Kmol of B reacted (from reaction) = 46.15 Kmol of B fed = Kmol of B reacted + Kmol of B unreacted = 46.15 + 11.54 = 57.69 kmol Inerts = 19.23 kmol	1 1 1

Component	Kmol	Mole %
A	115.38	60
B	57.69	30
Inerts	19.23	10

1