MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
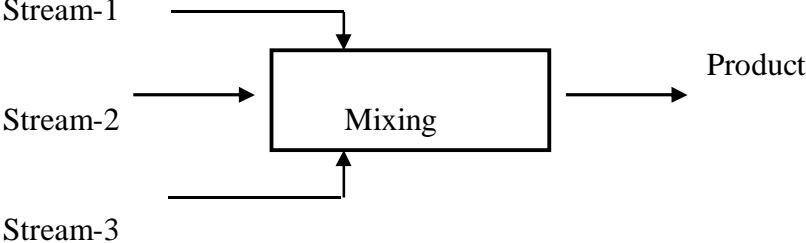
SUMMER-13 EXAMINATION

Model Answer

Subject & code : STI(12078)

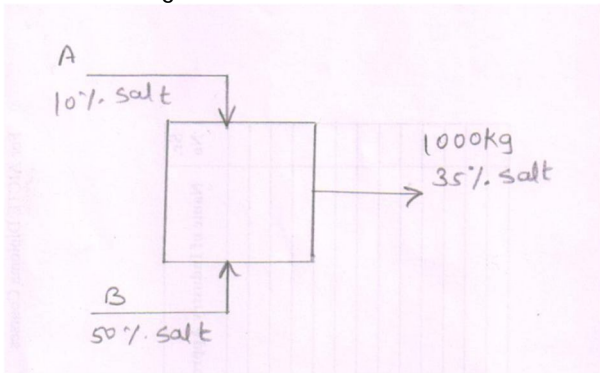Important instructions to examiners :

1. The answers should be examined by keywords 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 given more importance.
4. While assessing figures, examiner may give credit for principal components indicated in a 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 answer and model answer.
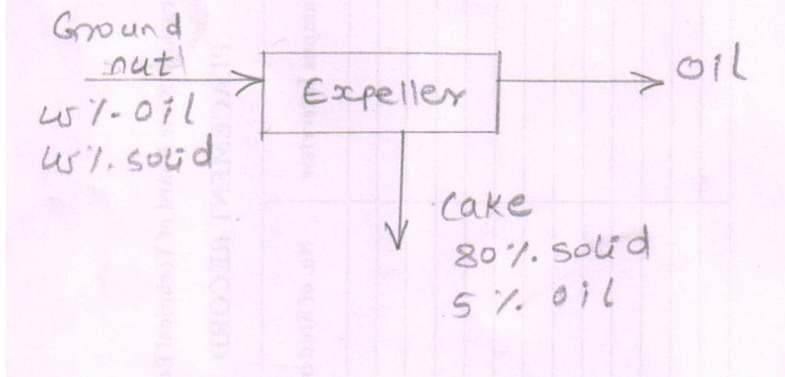6. In case of some questions credit may be given by judgment of relevant answer based on candidates understanding.

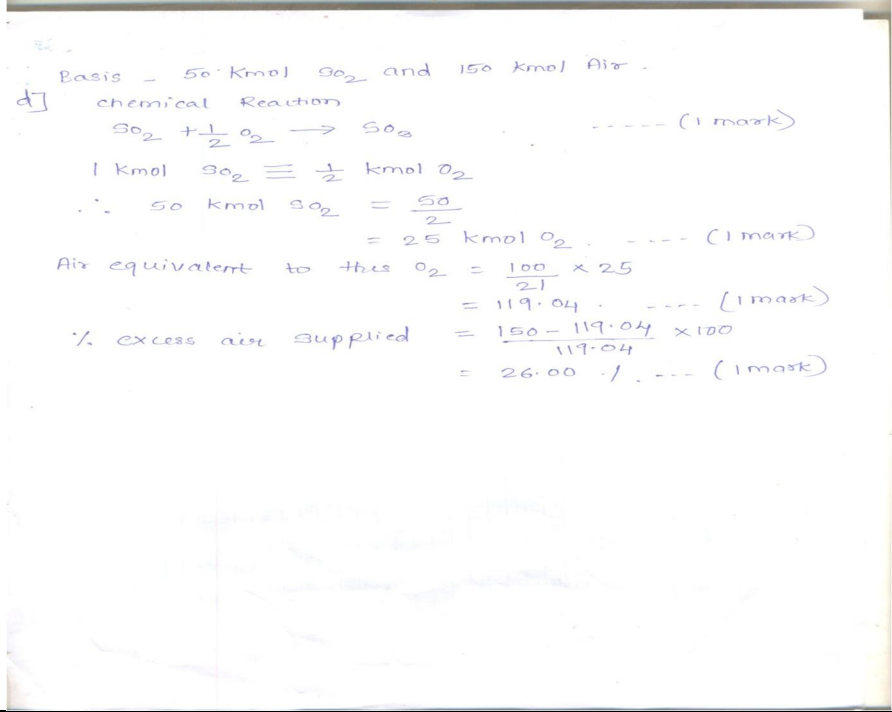| Q No:	Answer	Mark	Total marks
1-a	**Ideal gas equation is** PV=nRT Where P= pressure V=Volume n= number of moles R= Universal gas constant T= absolute temperature	2	2
1-b	**Amagat's law:** Amagat's law states that total volume occupied by a gas mixture is equal to the sum of pure component volumes.	1	2

	$V=V_A+V_B+V_C$ Where V is the total volume of gas mixture V_A, V_B, V_C are pure component volumes	1		
1-c	**Vander Waal's equation of state:** $(P+a/V^2)(V-b)= nRT$ Where a & b are constants.		2	2
1-d	**Yield of a chemical reaction** $= \dfrac{\text{moles of reactant reacted to form desired product}* 100}{\text{Total moles of reactant reacted}}$		2	2
1-e	**Stoichiometric equation:** It is defined as the balanced chemical reaction Eg: N_2+3H_2------$\rightarrow$2NH$_3$	1 1		2
1-f	At NTP conditions the values are P=1atm (101.325KPa) T=273 K V=22.41 m^3	2		2
1-g	**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 ΔH1 B $\longrightarrow$ C ΔH2 C $\longrightarrow$ D ΔH3 A $\longrightarrow$ D ΔH Then ΔH = ΔH1 +ΔH2+ ΔH3	1 1		2
1-h	**Law of conservation of mass:** It states that For any process input= output + accumulation	2		2
1-i	Stream-1 Stream-2 Mixing Product Stream-3	2		2
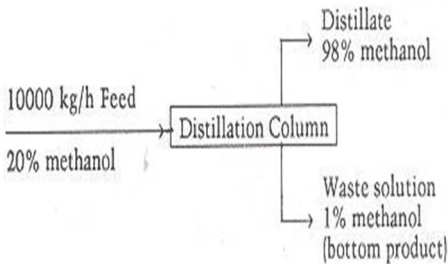
1-j	**Limiting component in a chemical reaction:**	2	2
	It is the reactant which decides the extent of a reaction.	Any	
	Or	definition	
	It is the reactant which is added in limited quantity.	may be	
	Or	given	
	It is the reactant which disappear first if a reaction goes to completion	mark	
1-k	**Standard heat of combustion:**	2	2
	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)		
1-l	Given data:150.46KPa.g		2
	Absolute pr= Gauge pressure + atmospheric pressure	1	
	=150.46+101.325		
	= 251.785 KPa	1	
2-a	Basis : 100 kg. azeotrope	1	4
	Weight of ethanol = 96 kg.		
	Kg moles of ethanol = 96/46 = 2.09	1	
	Weight of water = 4 kg.		
	Kg. moles of water = 4/18 = 0.22	1	
	Total moles = 2.31		
	Mole % of ethanol = 2.09 * 100/2.31 = 90.48%		
	Mole % of water = 0.22 * 100 /2.31 = 9.52%	1	
2-b	Weight of CO =N_2 = 100 kg.		4
	Kg. moles of CO = 100/28 = 3.57		
	Kg. moles of N_2 = 100/28 =3.57	1	
	Mole fraction of N_2 = 0.5	1	
	Total pressure = 405.3 KPa		
	Partial pressure of N_2 = total pressure * mole fraction of N_2	1	
	= 405.3 * 0.5 = 202.65 KPa	1	

2-c	con.H_2SO_4 $\longrightarrow$		
	Basis : 100 kg. mixed acid.	1	
	Weight of HNO_3 in mixed acid = 40 kg.	1	
	Weight of H_2SO_4 in mixed acid = 43 kg.		
	Weight ratio of H_2SO_4 to HNO_3 in mixed acid = 43/40 = 1.075	1	
	OR		
	Let weight of con.H_2SO_4 be X kg and weight of con.HNO_3 be Y kg	1	
	Balance for H_2SO_4		
	0.98X = 43 or X = 43.88 kg.	1	
	Balance for HNO_3		
	0.12 Y = 40 or Y = 333.33 kg.	1	
	Weight ratio of H_2SO_4 to HNO_3 fed=43.88/333.33=0.132	1	

In the 2-c cell, there is a flow diagram:
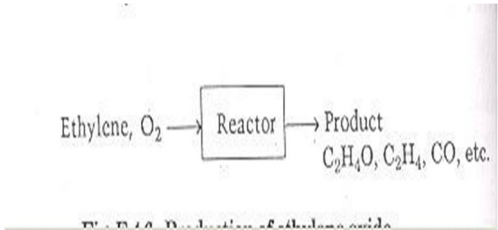
con.H_2SO_4 → [Mixing] → Mixed acid
con.HNO_3 →

with marks column showing 1 and total 4.

2-d	$SO_2 + \frac{1}{2} O_2 \longrightarrow SO_3$	1	4
	SO_2 fed = 100 kg. moles		
	SO_3 formed = 80 kg. moles	1	
	1 kg. mole SO_2 reacted = 1 kg. mole SO_3 formed		
	? = 80 kg. mole SO_3 formed	1	
	kg. mole SO_2 reacted = 80		
	% conversion of SO_2 =(SO_2 reacted /SO_2 fed)* 100	1	
	= 80*100/100 = 80%		

2-e	Mass flow rate of ethanol(m) = 100 kg./hr.	1	4
	Latent heat of vaporization of ethanol(λ) = 842.3KJ/kg.		
	Heat transferred to generate saturated ethanol vapour = m* λ	1	
	= 100*842.3		
	= 8423 KJ.	2	

2-f	C^0_{pm} = 29.3955KJ / (K mol. K)	1	4
	Moles of air (n) = 3		

	$T = 473K \quad T_0 = 298$		
	Heat added $Q = n* C^0_{pm} (T - T_0)$	1	
	$\quad = 3*29.3955(473-298)$		
	$\quad = 15432.64 \text{ KJ}$	2	
3-a	BASIS:1000 kg of final solution.	1	8
	Let kg of A=x Let kg of B=y Therefore overall balance X+y=1000 ....(1) Salt balance 0.1x+0.5y=1000*0.35 0.1x+0.5y=350 ....(2) Multiplying equation (1) by 0.1 0.1x+0.1y=100 ....(3) From eqution (2) and (3) 4y=250 Therefore y=250/4 =625kg X=375kg Wt of 10% solution=375 kg Wt of 50% solution=625kg	2 2 2 1	
3-b	Basis 100 kg of groundnut seeds.	1	8

		1	
	kg of solid=45kg kg of oil=45kg unchanging component is solid let weight of cake=x kg solid balance 0.8x=45 Therefore x=45/0.8=56.25kg Oil in cake=56.25*0.05 =2.81kg Therefore oil recovered=45-2.81 =42.19 % recovery of oil =(42.19/45)*100 =93.75	1 1 1 1 1	
3-c	detailed outline of the procedure for 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 algebric equations 8. Get values of two unknown quantities.	1 mark each	8

4-a	a) pv=nRT p=100kpa
	    v=5m^3
	    R=8.3145m^{3}kpa/kmol^{0}k
	    T=400^{0}K
	    Therefore n=pv/RT
	    =100*5/8.3145*400
		1
		
		1
		
		1
			4

	=0.15kmol Therefore wt of chlorine=0.15*71 =10.67 kg	1		
4-b	a) Basis 100 kmol/hr of N_2 $T_1=303$ $T_2=373$ $Q=m\int cp\Delta T$ $=100\,(\int 29.5905-5.1414*10^{-3}T+11.1829*10^{-6}T^2)$ $=100[(29.5905(T)-5.141*10^{-3}/2(T^2)+11.1829*10^{-6}/3(T^3)]_{303}^{373}$ $=100[2071.335-121.636+89.75]$ $=203.94*10^3$ kg/hr	1 1 2	4
4-c	Basis:2000kg/hr of mixture overall material balance D+W=2000 Benzene balance 0.98D +0.08w=2000*0.45 0.98D +0.08w=900 Multiplying eqution (1) by 0.08 0.08D+0.08W=160 ....(2) 90D=740 Therefore D=740/90 =822.22 kg/hr W=2000-822.22	1 1	4

	=1177.77
	% composition of Toulene=92%
	OR
	Benzene in bottom =1177.77*0.08
	                =94.22
	Therefore toluene in bottom=1177.77-94.22
	                =1083.54
	Therefore composition in bottom=1083.54
	% composition=(1083.54/1177.77)*100
	                =92%
		1
		1	

4d		1 1 1 1	4
4-e	general energy balance procedure 1.assume suitable basis of calculation 2.draw block diagram of the process and label the terms. 3.determine flowrates of all stream components. 4. determine the enthalpies of each stream component entering and leaving. 5.if chemical reaction is involved ,it must be included in the energy balance equation. 6. if heat capacity data is provided for components involved choose reference temp on which they are based.	4	4

4-f		1 1 1 1	4

For 4-f handwritten content:

f] Basis → 1 Kmol C_2H_4 Reacted.

Reaction

$C_2H_4 + \frac{1}{2}O_2 \longrightarrow C_2H_4O$ ---- (1 mark)

$\Delta H_R^0 = $ standard heat of reaction.

$= [\Sigma \Delta H_f^0]_{products} - [\Sigma \Delta H_f^0]_{reactants}$ --- (1 mark)

$= [1 \times \Delta H_{f\ C_2H_4O}^0] - [1 \times \Delta H_{f\ C_2H_4}^0 + \frac{1}{2}\Delta H_{f\ O_2}^0]$ $\frac{1}{2}$ mark

$= [1 \times (-52.63)] - [1 \times (52.50 + \frac{1}{2} \times (0.0)]$

$= -105.13$ kJ ----- (1 mark)

5-a	**Basis:** 10,000 Kg/hr of 20% methanol feed solution to column	1	8

Let X and Y be the mass flow rates of distillate and bottom product respectively

Overall Material Balance:

$$X + Y = 10{,}000 \quad \text{------- (i)}$$

Material Balance of Methanol :

$(98/100)*X + (1/100)*Y = (20/100)*10000$

$0.98*X + 0.01*Y = 2000$

$$Y = \frac{2000 - 0.98*X}{0.01}$$

$Y = 200000 - 98*X \quad \text{------- (ii)}$

Put the value of Y in Equation(i)

(marks column for 5-a: 1, 1, 1)

	X + (200000 - 98*X) = 10,000		
	200000 - 10000 = (98 – 1) * X		
	By solving **X =1959 Kg/hr** Put in equation (i)		
	Y= 10000 – X = 10000 -1959 = 8041 Kg/hr	1	
	Y= 8041 kg/hr		
	Mass flow rates of distillate = **1959 Kg/hr** ---- ans. (a) Mass flow rates of bottom Product = **8041 kg/hr** ---- ans.(a)		
	Methanol in Waste solution = 0.01 * 8041 = **80.41 Kg/hr** Methanol in feed = 0.2 *10000 = **2000 Kg/hr**	1	
	% loss of Methanol = $\dfrac{\text{Methanol in Waste Solution}}{\text{Methanol in Waste Solution}}$ * 100	1	
	% loss of Methanol = $\dfrac{80.41}{2000}$ * 100		
	% loss of Methanol = 4.02 % -------- ans. (b)	1	
5-b	**Basis :** 100 Kmol of ethylene fed to a reactor.	1	8
		1	
	Reaction 1 : $C_2H_4 + \frac{1}{2} O_2 \longrightarrow C_2H_4O$ Reaction 2 : $C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$	1	

Amount of C_2H_4O produced = 80 Kmol

Amount of CO_2 produced = 10 Kmol

C_2H_4 reacted to produce C_2H_4O by Reaction 1

$$= \frac{1}{1} * 80 = 80 \text{ Kmol}$$

From Reaction 2,

   1 Kmol C_2H_4 $\equiv$ 2 Kmol CO_2

C_2H_4 reacted to produce 10 Kmol CO_2 by reaction 2

$$= \frac{1}{2} * 10 = 5 \text{ Kmol}$$

C_2H_4 totally reacted = C_2H_4 reacted by reaction 1 +

                          C_2H_4 reacted by reaction2

$$= 80+5 = 85 \text{ Kmol}$$

$$\% \text{ conversion of } C_2H_4 = \frac{C_2H_4 \text{ totally reacted}}{C_2H_4 \text{ totally feed}} * 100$$

$$= \frac{85}{100} * 100 = 85 \%$$

% conversion of C_2H_4 = 85 % ------ ans. (a)

$$\% \text{ yield of } C_2H_4O = \frac{\text{Kmol } C_2H_4 \text{ reacted to Produce } C_2H_4O}{C_2H_4 \text{ totally reacted}} * 100$$

$$= \frac{80}{85} * 100 = 94.12 \%$$

% yield of C_2H_4O = 94.12% ------ ans. (b)

5-c	**Basis :** 1 mol of gaseous ethyl alcohol	1	8
	1. $C(s) + O_2(g)$ ------> $CO_2(g)$ $\quad \Delta H_1 = -393.51$ KJ/mol		
	2. $H_2(g) + 1/2\, O_2(g)$ ------> $H_2O(l)$ $\quad \Delta H_1 = -285.83$ KJ/mol		
	3. $C_2H_5OH(g) + 3\,O_2(g)$ ------> $2CO_2(g) + 3H_2O(l)$	2	
	$\Delta H^0c = -1410.09$ KJ/mol		
	4. $2C(s) + 3\,H_2(g) + 1/2\,O_2(g)$ ------> $C_2H_5OH(g)$		
	$\Delta H^0f = ?$		
	ΔH^0f = Standard heat of formation of gaseous ethyl alcohol At 2198.15 K		
	Reaction(4) = 2* Reaction (1) + 3* Reaction (2) – Reaction (3)	2	
	$\Delta H^0f = 2*\Delta H_1 + 3*\Delta H_2 - \Delta H^0c$		
	$= 2(-393.51) + 3*(-285.83) - (-1410.09)$	2	
	$= (-787.02) + (-857.49) - (-1410.09$		
	$= -234.42$ KJ/mol		
	ΔH^0f = -234.42 KJ/mol ------- ans.	1	
6-a	**Basis:** 4 Kmol of FeS_2	1	8
	$4\,FeS_2 + 11\,O_2$ -------> $2Fe_2O_3 + 8\,SO_2$		
	Theoretical requirement of $O_2 = \dfrac{11}{4} * 4 = 11$ kmol		
	O_2 reacted = O_2 theoretically required = 11 Kmol		
	Theoretical requirement of air = $11 * \dfrac{100}{21} = 52.38$ kmol	1	
	Air is used 60% in excess		

		1	
	Air supplied = 52.38 * (1 + $\frac{60}{100}$) = 83.80 kmol		

Amount of O_2 in supplied Air = 83.80 * $\frac{21}{100}$ = 17.6 kmol

Amount of N_2 in supplied Air = 83.80 - 17.6 = 66.20 kmol

Amount of O_2 unreacted = 17.6 – 11 = 6.6 kmol

From reaction,

4 kmol FeS_2 = 8 kmol SO_2

Amount of SO_2 produced = $\frac{8}{4}$ * 4 = 8 kmol

N_2 in the gas leaving = N_2 in air supplied = 66.20 kmol

Composition of Gases :

Component	Quantity in kmol	Mole %
O_2	6.6	8.17
N_2	66.20	81.93
SO_2	8.0	9.9
Total	80.8	100

(marks column: 1, 1, 1, 1, 2)

6-b | **Basis :** Gas sample containing CH_4, CO_2 and NH_3
For ideal gases, Volume % = Mole %
Mole % of CH_4 = 66, Mole % of CO_2 = 30, Mole % of NH_3 = 4

Mole Fraction of CH_4 = X_{CH_4} = $\frac{\text{Mole \% of } CH_4}{100}$ = $\frac{66}{100}$ = 0.66

Mole Fraction of CO_2 = X_{CO_2} = $\frac{\text{Mole \% of } CO_2}{100}$ = $\frac{30}{100}$ = 0.30

Mole % of NH_3 4

(marks column: 1, 1 | 8)

	Mole Fraction of NH3 = X NH3 = -------------------- = ------- = 0.04 100 100	1	

M_{avg} = Average molecular weight of gas
= M CH4 * X CH4 + M CO2 * X CO2 + M NH3 * X NH3
= (16*0.66)+(44*0.30)+(0.04*17) = 24.44

M_{avg} =24.44 --------- ans.(a)

$$ \text{Density of gas mixture } = \rho = \frac{P\ M_{avg}}{R\ T} $$

Absolute Pressure = Gauge Pressure + Atmospheric Pressure
     P = 202.65 + 101.325 = 303.975 KPa
T = 303 K , M_{avg} = 24.44 , R= 8.31451 m^3.Kpa/(kmol.K)

$$ \rho = \frac{(303.975 * 24.44)}{(8.31451 * 303)} = 2.95\ kg/m^3 $$

Density of gas mixture = ρ = 2.95 kg/m^3 ------- ans.(b)

1		
1		
1		
1		
1		
1		

6-c | **Basis :** 100 kg of fresh juice fed to the process | 1 | 8

Fresh juice 100 kg 15% solids — 15% solids (x) → Evaporator 55% solids (z) → (p) Concentrated juice 40% solids
(y) bypass juice 15% solids

Let 'X' and 'Y' be the kg of juice fed to the evaporator and kg of juice bypasses the evaporator

Let 'Z' be the kg of juice leaving the evaporator and 'P' be the kg of concentrated juice obtained.

Overall Material Balance before evaporation

     X + Y = 100 ------- (i)

Material Balance of Solids over evaporation

$$0.15 \ X = 0.55 \ Z \quad \text{------ (ii)}$$

Overall Material Balance after evaporation

$$Z + Y = P \quad \text{------- (iii)}$$

Material Balance Solids after Evaporation

$$0.55 \ Z + 0.15 \ y = 0.4 \ P \ \text{----- (iv)}$$

Put value of 'P' from equation (iii) in equation(iv)

$$0.55 \ Z + 0.15 \ Y = 0.4 \ (Z + Y) \quad \text{------ (v)}$$

From equation (i) , we have,

$$X = (100 - Y) \ \text{---------- (vi)}$$

From equation (ii) ,we have,

$$0.15 \ X = 0.55 \ Z$$

$$0.15(100-Y) = 0 \ 0.55 \ Z$$

$$Z = \ \frac{15 - 0.15 \ Y}{0.55}$$

$$Z = 27.27 - 0.2727 \ Y$$

Put the value of Z in equation (v) and solve it for Y

$$0.55(27.27 - 0.2727 \ Y) + 0.15 \ Y = 0.4 \ Y + 04 \ (27.27 - 0.2727 \ Y)$$

$$Y = 14.06 \ Kg$$

Fraction of juice that bypass evaporation in percent

$$= \frac{Y}{100} \ * \ 100$$

$$= \frac{14.06}{} \ * \ 100$$

100

$= 14.06 \ \%$

Fraction of juice that bypass evaporation = 14.06 %

----- ans.

1