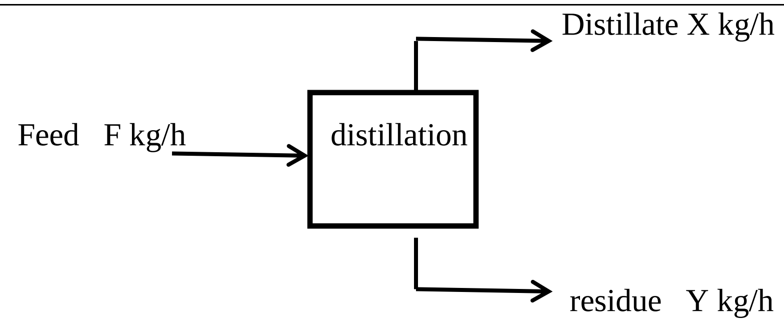
SUMMER-18 EXAMINATION

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
1A	**Any 4**	**8**
1A-a	**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
1A-b	**Ideal gas equation is** PV=nRT Where P= pressure V=Volume n= number of moles R= Universal gas constant T= absolute temperature Value and unit of R is **8.314 KPa m^3/ kmol K**	 1 1
1A-c	**Standard heat of formation** : It is the amount of heat liberated or absorbed when one mol of a compound is formed from its elements at standard conditions. **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)	1 1
1A-d	**Block diagram for distillation:**	

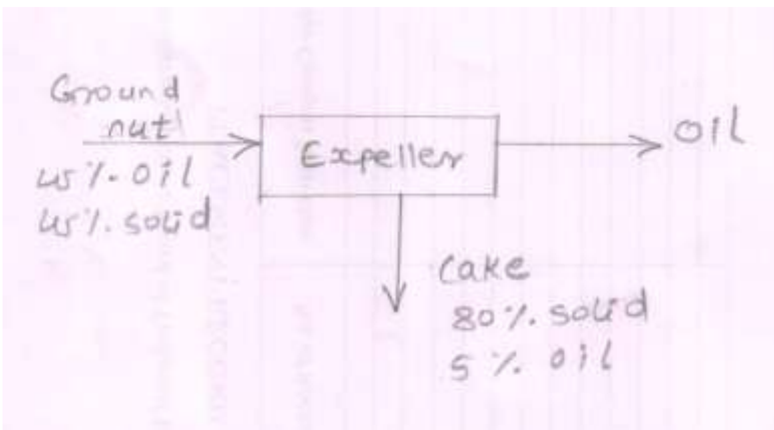
		1
	Overall balance is F = X+ Y	1
1A-e	20 kg Cl_2 Molecular weight of Cl_2=71 Moles of Cl_2 = weight / molecular weight = 20 / 71 = 0.282 kmoles PV=nRT P = 100 KPa T= 298 K V= nRT/P = 0.282 * 8.314 * 298 / 100 = **6.98 m^3**	 1 1
1A-f	**105.6 KPa .g** Absolute pr = Gauge pr + atmospheric pr **=** 105.6 + 101.325 **= 206.925 KPa**	 1 1
1-B	**Any 2**	**12**
1-B a	Basis: 15 kg liquid propane Kmoles of propane = 15/ 44 = 0.341 PV = nRT V = nRT/P	 2 1

	P = 101.325 KPa R = 8.314 m^3kPa/ kmol.K T = 273 K	1
	V= 0.341 * 8.314 * 273 / 101.325	1
	= 7.638 m^3	1
1-B b	Basis: 100 kmol gas sample	1
	Avg. mol.wt of air = $M_1X_1+ M_2X_2$	1
	= 32 * 0.21 + 28 * 0.79	
	= **28.84**	1
	Density = P* Mav / RT	1
	= 1519.875 * 28.84/ 8.314 * 503	
	= **10.48 Kg/m^3**	2
1-B c	**To prove mol% of A = Mol fr of A * 100**	
	Mol % of A = (Moles of A / Total moles of the system) * 100 ……..(1)	2
	Mol fraction of A = (Moles of A / Total moles of the system) ……(2)	2
	Comparing (1) and(2)	
	Mol % of A = Mole fraction of A * 100	2
2	**Any 4**	**16**
2-a	**Steps involved in solving material balance without chemical reactions:**	4
	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:	

	feed	product	Component removed
Unchanging component			
Outgoing component			

2-b

Basis: 100 kg of groundnut seeds.



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 1

Oil in cake=56.25*0.05

=2.81kg

Therefore oil recovered=45-2.81

=42.19 1

	% recovery of oil =(42.19/45)*100 =**93.75 %**	 1
2-c	$SO_2 + ½ O_2 \longrightarrow SO_3$ SO_2 fed = 100 kg. moles SO_3 formed = 80 kg. moles 1 kg. mole SO_2 reacted = 1 kg. mole SO_3 formed ? = 80 kg. mole SO_3 formed kg. mole SO_2 reacted = 80 % conversion of SO_2 =(SO_2 reacted /SO_2 fed)* 100 = 80*100/100 = **80%**	 1 1 1 1
2-d	**i)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. For example, the stoichiometric equation $CO + 2 H_2$------→ CH_3OH Indicates that one molecule of CO react with two molecules of hydrogen to produce one molecule of methanol **ii)Stoichiometric ratio :** It is the ratio of stoichiometric coefficient of two molecular species or Components in the balanced reaction For example, in the stoichiometric equation $CO + 2H_2$------→ CH_3OH Stoichiometric ratio of H_2 to CO = 2:1 **(Students may write other suitable example)**	 1 1 1 1

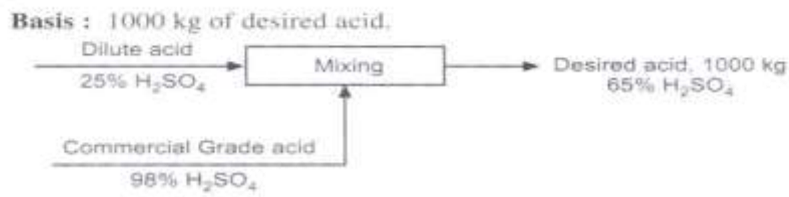
2-e	Basis – 50kmol SO_2 150 kmol air Reaction $SO_2 + \frac{1}{2}O_2 = SO_3$ Air fed = 150kmol O_2 in air = 150 × (0.21) = 31.5 kmol Theorctical requirement of O_2 1 Kmol $SO_2 \equiv$ 0.5 kmol O_2 $= \frac{0.5}{1} \times 50$ = 25 kmol $\therefore$% excess of O_2 used $= \frac{O_2 \text{ in supplied} - O_2 \text{ theo read}}{O_2 \text{theo read}}$ $= \frac{31.5-25}{25} \times 100$ = 26 $\therefore$ % excess air used = **26%** **OR** Theo.air reqd $= \frac{100}{21} \times 25$ = 119.05 Kmol $\therefore$% excess air used $= \frac{150-119.05}{119.05}$ **= 26%**	1 1 1 1
2-f	C^0_{pm} = 29.3955kJ / (K mol. K) Moles of air (n) = 3	

	$T = 473K$ $T_0 = 298$	1
	Heat added $Q = n^* C^0_{pm} (T – T_0)$	1
	= 3*29.3955(473-298)	
	= **15432.64 kJ**	2
3	**Any 2**	**16**
3-a	**Basis :** 100 Kmol of feed Feed contains 60 kmol A , 30 kmol B and 10 kmol inerts Let X be the kmol of A reacted by reaction : 2A + B ----- C A reacted = 0.8*60 = 48 kmol C From reaction B reacted = (1/2)* 48 = 24 kmol C formed = (1/2)* 48 = 24 kmol Product stream contains unreacted A, unreacted B, product C and inert Unreacted A = 60-48 = 12 kmol B unreacted = (30 - 24) kmol =6 kmol Total moles of product stream = 12 + 6 + 24 + 10=52 kmol Composition of product stream:	1 2 1 2

component	kmoles	Mol%
A	12	23.08
B	6	11.54
C	24	46.15
inert	10	19.23

(marks: 2)

3-b	**Basis :**1000 Kg of desired acid	1



1

Let X and Y be the kg of dilute acid and Commercial Grade required to prepare desired acid.

Overall Material balance

Kg dilute acid + kg Commercial Grade = Kg of desired acid 1

X + Y = 1000 -------------(1)

Material Balance of H_2SO_4 1

H_2SO_4 in dilute acid + H_2SO_4 in Commercial Grade = H_2SO_4 in desired acid

1

0.25 X +0.98 Y = 0.65 * 1000

0.25X + 0.98Y = 650

$$Y = \frac{650 - 0.25\,X}{0.98}$$ 1

Y=663.23 - 0.255 X put in equation (1)

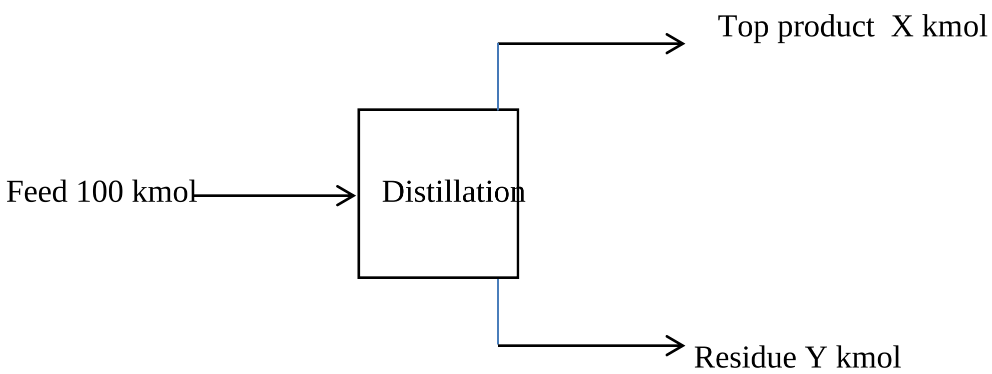
X + (663.26 – 0.255 X) = 1000

X= 452 kg

We have,

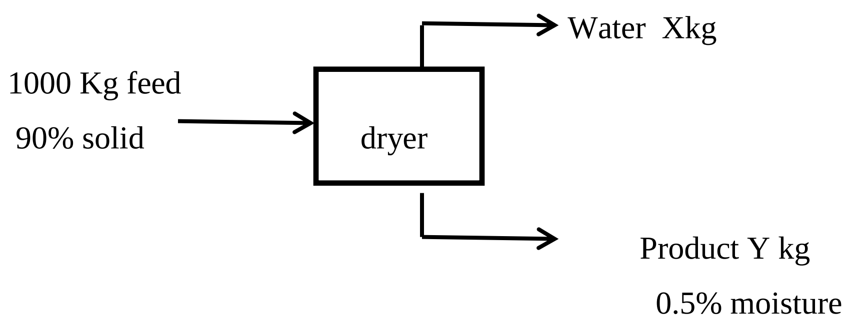
X +Y =1000

452 + Y =1000

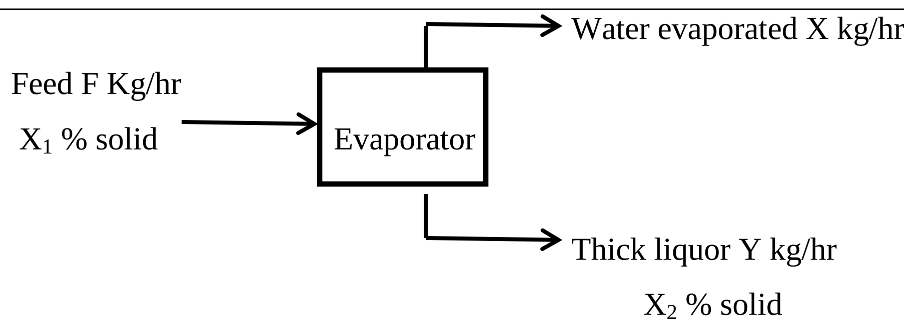
	Y = 548 Kg **Dilute acid required = 452 Kg** **Commercial Grade Acid required =548 kg**	2
3-c	Basis : 1000 kmol Benzen- Toluene mixture  Let X and Y be the mass flow rates of distillate and bottom product respectively **Overall Material Balance:** X + Y = 1000 ------- (i) **Material Balance of benzene:** (52/100)*X + (5/100)*Y = (28/100)*1000 0.52*X + 0.05*Y = 280 By solving **X =489.36Kg/hr** **Y= 510.64 kg/hr** Mass flow rates of distillate = **489.36Kg/hr** ---- ans. (a) Mass flow rates of bottom Product = **510.64 kg/hr** ---- ans.(a) Benzene in distillate = 0.52 * 489.36 = **254.47 Kg/hr** Benzene in feed = 0.28 *1000 = **280 Kg/hr**	1 1 1 1 2

	% recovery of benzene = (benzene in distillate / Benzene in feed) * 100	1
	% recovery of benzene = (254.47 / 280) * 100	1
	% recovery of benzene = 90.88 % -------- ans. (b)	
4	**Any 2**	**16**
4-a	Basis 1mol of n propanol liquid	
	1) $C (s) + O_2 (g) = CO_2 (g)\ \Delta H_1 = -393.51 \frac{KJ}{mol}$	2
	2) $H_2 (g) + \frac{1}{2} O_2 (g) = H_2O (e)\ \Delta H_2 = -285.83 \frac{KJ}{mol}$	2
	3) $C_3H_7OH (l) + 4.5O_2 = 3CO_2 + 4H_2O\ \Delta Hc = -2028.19 \frac{KJ}{mol}$	2
	$\Delta H_+ C_3H_7OH$ = Heat of formation of n propanol	
	$= 3\Delta H_1 + 4\Delta H_2 - \Delta H^0C$	
	= 3 (-393.51) + 4 (-285.83) – (-2028.19)	2
	= - 295.66 kJ/mol.	
4-b	**Basis :** 100 Kg of Soyabean seeds	1
	It contains 18.6 kg oil ,69 kg solids and 12.4 kg moisture	
	Let X be the Kg of cake obtained	
	Material balance of Solids :	
	Solids in seeds = Solids in cake	2
	0.69 * 100 = 0.877* X	

	X = 78.68 Kg **Material balance of Oil :** Oil in seeds = Oil in cake + Oil recovered 0.186* 100 = 0.008* 78.68 + Oil recovered 18.6 = 0.6294 + Oil recovered Oil recovered = 18.6 – 0.6294 =17.97 Kg	2
	% recovery of Oil = Oil recovered / Oil in Seeds * 100	1
	% recovery of Oil = 17.97 / 18.6 * 100	1
	% recovery of Oil = 96.61 % ----------- ans.	1
4-c	**To prove Pressure % = Mol % = Volume %**	
	Ideal gas law is PV = nRT ……….(1)	1
	Ideal gas law for component gas A(partial pressure) is	
	P_A V = n_ART ………(2)	1
	(2) / (1)	
	P_A V / PV = n_ART / nRT	1
	P_A / P = n_A / n	
	Multiplying both sides by 100, we get	1
	(P_A / P)* 100 = (n_A / n) * 100	
	Pressure % = Mol % ………..(3)	1
	Ideal gas law for component gas A(pure component volume) is	
	P V_A = n_ART ………(4)	1

	(4) / (1) $P V_A / PV = n_A RT / nRT$ $V_A / V = n_A / n$ Multiplying both sides by 100, we get $(V_A / V)* 100 = (n_A / n) * 100$ Volume % = Mol % ………..(5) Comparing (3) and(5) We can write **Pressure % = Mol % = Volume %**	 1 1
5	**Any 2**	**16**
5-a	Basis: 1000 kg wet ONA  Overall balance is 1000 = X+ Y Balance for solid 0.90 * 1000 = 0.995 * Y Y = 904.52 kg X = 95.48**kg** Water removed = 95.48**kg** Product obtained = **904.52 kg** **% of original water removed = (**Water removed/original water 0*100	1 1 1 1 2 1

	= (95.48/100)*100 =**95.48%**	1
5-b	**Basis:** 100 Kmol/min of CO_2 Q= Heat added $= n\int_{T_1}^{T_2} Cp\, dT$ $= n\int_{T_1}^{T_2} [21.3655 + 64.2841 \times 10^{-3} T - 41.0506 \times 10^{-6} T^2 + 9.7999 \times 10^{-9} T^3]\, dT$ $= n\ [21.3655 (T_2 - T_1) + 64.2841 \times 10^{-3}/2 (T^2_2 - T^2_1)$ $- 41.0506 \times 10^{-6}/3 (T^3_2 - T^3_1) + 9.7999 \times 10^{-9}/4 (T^4_2 - T^4_1)]$ Where n= 100 kmol/min , T_2 = 383 K, T_1=298 K $= 100 [21.3655 (383 - 298) + 64.2841 \times 10^{-3}/2 (383^2 - 298^2) - 41.0506 \times 10^{-6}/3 (383^3 - 298^3) + 9.7999 \times 10^{-9}/4 (383^4 - 298^4)]$ = 330335.5 KJ/min = 5505.6 KJ/s **Q = 5505.6 KW --------------- Ans.**	01 02 02 02 01
5-c	**Basis:**1 mol of gaseous ethanol reacted $C_2H_5OH(g) \longrightarrow CH_3CHO(g) + H_2(g)$ 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 2 3

	= [1 x -1410.09)] – [1 x (-1192.65) + 1 x (-285.83)] = -1410.09 + 1478.48 **= 68.39 KJ ----- Ans.** ***Note: Instead of -1192.65, if the student calculated with the value of -11.9265,the answer will be -1112.33kJ. Full marks should be given.***	2
6	**Any 4**	**16**
6-a	**Vander Waal's equation of state:** $(P+a/V^2)(V-b)= nRT$ Where a & b are constants. $A= 27 R^2 T_c^2 / 64 P_c$ lit ^{2} . Mpa / mol ^{2} $B = RT_c / 8 P_c$ Tc & Pc = Critical Temperature and Pressure	2 1 1
6-b	 Overall Material balance is F = X + Y	3 1
6-c	**Heat capacity:** It is the amount of heat required to increase the temperature of one kg of substance by 1 K. It is expressed on a unit mass or unit mole basis. **Heat of combustion:** It is the amount of heat liberated when one mole of a compound is combusted or burned in oxygen. The combustion reaction proceeds with a reduction in enthalpy of a system, hence heat of combustion is	2 2

	negative.	
6-d	**Hess's law of constant heat summation :** It states that the enthalpy change i.e. heat evolved or absorbed in a particular reaction is the same whether the reaction takes place in one or several steps. For Example : Carbon can be converted into CO_2 by two ways Path 1 : $C (s) + O_2 (g) \longrightarrow CO_2 (g)$ ----- ΔH Path 2 : (i) $C (s) + ½ O_2 (g) \longrightarrow CO (g)$ ----- $\Delta H1$ (ii) $2CO (g) + ½ O_2 (g) \longrightarrow CO_2 (g)$ ----- $\Delta H2$ -- (i) + (ii) $C (s) + O_2 (g) \longrightarrow CO_2 (g)$ Thus $\Delta H = \Delta H1 + \Delta H2$	2 2
6-e	**Differentiate Conversion and Yield :**	1 mark each for any 4 points

Conversion	**Yield**
1.Conversion is the ratio of the amount of reactant reacted to the initial amount of the reactant	**1. Yield** of a desired product is the ratio of the quantity of the desired product actually obtained to its quantity maximally obtainable.
2. Conversion gives us idea regarding how efficient a given chemical process is from the point of view of utilization of the starting materials.	**2.** The **Yield** of a desired product tell us how efficient is a given chemical process is in terms of the reaction product.
3. Higher values of **Conversion** is the indication of minimum amount of the limiting reactant left unreacted.	**3.** Higher values of **Yield** is the indication of minimum occurrence of side reactions.

	4. Conversion is applicable to single reactions as well as to Complex reaction. **5. Conversion** may have low to high values –maximum 100% | **4. Yield** is applicable to Complex reaction **5. Yield** should have always higher values ,maximum : less than 100%	
6-f	**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 3. Utilization 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 product	1 ¾ marks each