WINTER-15 EXAMINATION

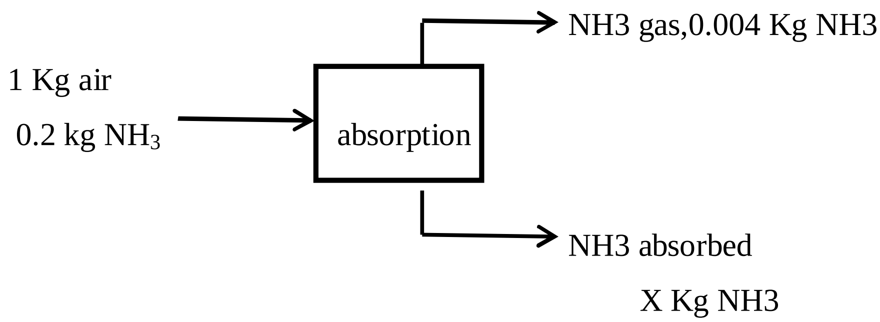
Model Answer

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.

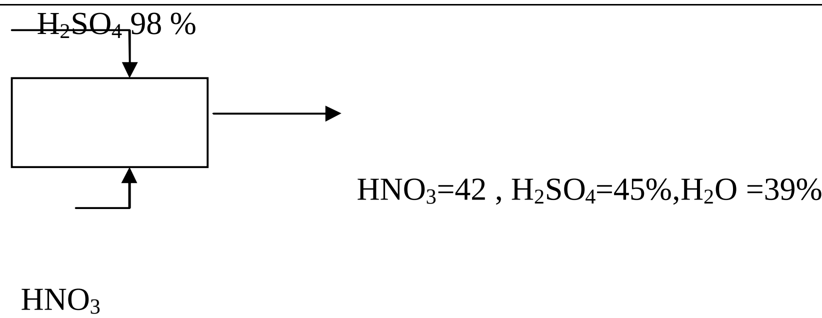
Q No.	Answer	marks	Total marks
1-A	Any 4		8
1A-a	**Ideal Gas law:** PV=nRT where P - pressure, V - volume, n- moles, K-absolute temperature and R – universal gas constant	1 1	2
1A-b	**Principle involved in solving material balance problems without chemical reaction:** **Law of conservation of mass:** It states that For any process input= output+accumulation	2	2
1A-c	**Amagat's law:** It states that the total volume exerted by a gas mixture is equal to the sum of pure component volumes **Mathematical Statement**: $V = V_1 + V_2 + V_3$ where V is the total volume of gas mixture , V_1, V_2, V_3 are pure component volumes	1 1	2
1A-d	**Raoult's law:** Raoult's law states that equilibrium partial pressure of a constituent at a given temperature is equal to the product of its vapour pressure in pure state and its mol fraction in the liquid phase. $P_A = P^0_A X_A$	2	2
1 A-e	**Adiabatic reaction :** It is the reaction which proceeds without loss or gain of heat. **Adiabatic reaction temperature:** Temperature of product under adiabatic condition is called adiabatic reaction temperature.	1 1	2
1A-f	**% Conversion:** It is the ratio of amount of limiting reactant reacted to the amount of limiting reactant totally charged. Express in percentage. **%Yield of desired product =** (moles of limiting component reacted to form	1 1	2

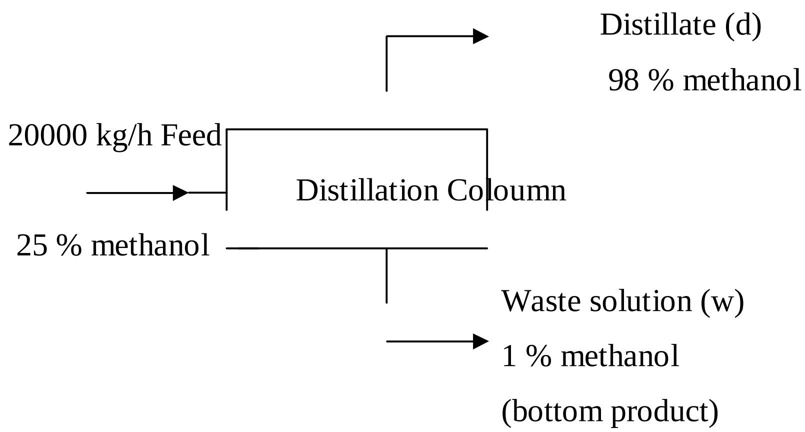
	desired product/ total moles of limiting component reacted)* 100		
1-B	**Any 2**		12
1B-a	**Basis: 100 kmoles of air** Average mol.wt of air= 0.79*28+0.21*32= 28.84 Density of air = P*Mav/ RT At NTP, P= 101.325 KPa, R= 8.314, T=273 K Density = **1.29 kg/m^3**	1 1 1 1	4
1B-b	Partial pressure of CO_2 in gas phase P_{CO2}= H * x_{CO2} =$7*10^6*4*10^{-6}$ = **28 KPa**	2 2	4
1B-c	Basis: 0.8m^3 fixed mass of gas at constant temperature P_1 =1 V_1= 0.8 m^3 T_1= T= T_2 P_2 =1.5 V_2= ? m^3 $P_1V_1/T_1 = P_2V_2/T_2$ 1*0.8/T = 1.5*V_2/T Or V_2**= 0.533 m^3**	1 1 1 1	4
2	Any 4		16
2-a	**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 algebric equations	½ mark each	4

	8. Get values of two unknown quantities.		
2-b	Basis: 1 kg air  NH3 balance is 0.2= 0.004+ X X= 0.196 Kg % recovery of ammonia = (NH3 absorbed/ NH3 original)*100 = (0.196/0.2)*100 = **98%**	1 1 1 1	4
2-c	**Excess component:** It is the reactant which is in excess of the theoretical or stoichiometric requirement. **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.	2 2	4
2-d	**Basis:** 100 of ethanol charged. C_2H_5OH -----→ $CH_3CHO + H_2$ I kmol C_2H_5OH reacted = 1kmol CH_3CHO formed C_2H_5OH reacted to produce 45 kmol CH_3CHO = 45 kmol Conversion of C_2H_5OH =(kmole of C_2H_5OH reacted/ kmoles Of C_2H_5OH fed)*100	1 1 1	4

	=(45/100)*100 % conversionof ethanol = **45 %**	1	
2-e	Basis – 100Kmol SO_2 charged O_2 fed=75 kmoles Reaction $SO_2 + \frac{1}{2}O_2 = SO_3$ Theorctical requirement of O_2 1 Kmol $SO_2 \equiv$ 0.5 Kmol O_2 theoretical 100 kmol $SO_2 = \frac{0.5}{1} \times 100$ Theorctical O_2 = 50 Kmol $\therefore$% excess of O_2 used $= \frac{O_2 \text{ in supplied} - O_2 \text{ theo read}}{O_2 \text{theo read}}$ $= \frac{75-50}{50} \times 100$ =50 $\therefore$ % excess air used = **50%**	1 1 1 1	4
2-f	Basis: 100 Kg/hr C_2H_5OH m=100 Kg/hr λ= 202 kcal/kg Latent heat = m. λ = 100 *202 = **20200 Kcal / hr**	1 2 1	4
3	Any 2		16
3-a	**SOLUTION :**		8

	BASIS : 100 mol of ethylene **Reaction I** $C_2H_4 + ½ O_2 \longrightarrow C_2H_4O$ **Reaction II** $C2H4 + 3O2 \longrightarrow 2CO2 + 2H2O$ From reaction I, 1Kmol of C2H4O formed = 1Kmol C2H4 reacted ∴ C2H4 reacted to form 80 kmol C2H4O $= \frac{1}{1}$ x 80 = 80Kmol From reaction II, 2kmol of CO2 formed = 1Kmol C2H4 reacted ∴ C2H4 reacted to form 10 kmol CO2 $= \frac{1}{2}$ x10 = 5Kmol ∴ C2H4 totally reacted = 80 + 5= 85 ∴ % conversion of C2H4 = $\frac{85}{100}$ x 100 = **85%** % yield of C2H4O = $\frac{80}{85}$ x100 = **94.12%**	2 1 1 2 2	
3-b	**SOLUTION :** **BASIS :** 100 kg of mixed acid ∴ H_2SO_4 =45 Kg HNO_3 = 42 Kg		8

		2	
	Let, X be the kg of H_2SO_4 and		
	Y be the kg of HNO_3		
	x + y = 100		
	Material Balance on H_2SO_4 :-	1	
	0.98x = 45		
	∴ x= 45/0.98		
	x= 45.91		
	∴ weight of H_2SO_4 = 45.91 kg		
	∴ weight of HNO_3 = 100-45.91= 54.09 kg		
	Let , y is strength of HNO_3	2	
	∴ 54.09 y = 42		
	y = 42/54.09	1	
	y = 0.7764		
	∴ strength of HNO_3 = 0.7764 x 100		
	= **77.64 % …………Ans.**	1	
	$\frac{\text{Weight ratio of } H_2SO_4}{\text{Weight ratio of } HNO_3} = \frac{45.91}{54.09}$		

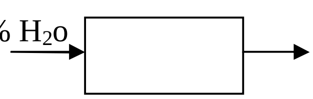
<table>
<tr><td></td><td>= 0.8487…………….Ans.</td><td>1</td><td></td></tr>
<tr><td>3-c</td><td>SOLUTION :
BASIS : 20,000 kg /h of 25 % methanol feed solution to coloumn.

Block diagram for distillation of 25 % methanol feed

Let x and y be the mass flow rates of distillate / product and waste solution (bottom product) respectively.

Overall Material Balance :
$x + y = 20000$….(i)

Material Balance of Methanol :
$0.98\ x + 0.01\ y = 0.25 \times 20000$
$0.98\ x + 0.01\ y = 5000$ ….(ii)
From equation(i) ,</td><td>2
1
1</td><td>8</td></tr>
</table>

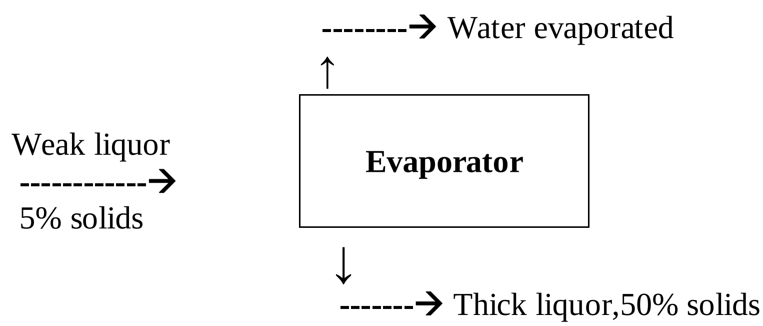
	y = 20000 - x ….(iii) Put the value of y from equation (iii) in eqn (ii) and solve for x. 0.98 x + 0.01 (20000 – x) = 5000 0.98 x – 0.01 x = 5000 – 200 0.97 x = 4800 x = 4948.45 kg/h ∴ y = 20000 - x = 20000 – 4948.45 = 15051.55 kg/hr Mass flow rate of distillate = **4948.45 kg/h** Mass flow rate of waste solution **= 15051.55 kg/hr ….Ans.** Methanol in waste solution = 0.01 x15051.55 = 150.51 kg /h Methanol in Feed = 0.25 x 20000 = 5000 kg /h % loss of methanol = $\frac{\text{Methanol in waste solution}}{\text{Methanol feed solution}}$ x 100 = $\frac{150.51}{5000}$ x 100 **= 3.01 % …Ans**	2 1 1	
4	Any 2		16
4-a	**SOLUTION :** **Basis :** 1 mol of C4H6 (liq) 1. C(s) + O2(g) ------> CO2(g) ΔH1 = - 393.51 KJ/mol 2. H2 (g) +1/2 O2(g) ------> H2O(l) ΔH1 = - 285.83 KJ/mol	 1 1	8

	3. C4H6 (liq.) +5.5 O2(g) ------> 4CO2(g)+3 H2O(l) ΔH0c = - 2520.11 kJ/mol 4. 4C(s) + 3 H2 (g) ------> C4H6 (liq.) $\Delta H^0 f$ = ? $\Delta H^0 f$ = Standard heat of formation of gaseous ethyl alcohol at 298.15 K Reaction(4) = 4* Reaction (1) + 3* Reaction (2) – Reaction (3) $\Delta H^0 f = 4*\Delta H1 + 3*\Delta H2 - \Delta H^0 c$ = 4(-393.51) + 3*(-285.83) – (-2520.11) = (-1547.04) + (-857.49) +1410.09 = 88.58 KJ/mol ΔH0f = **88.58 KJ/mol ------- Ans.**	1 1 1 2 1	
4-b	**SOLUTION :** **BASIS :** 1000 kg of wet solid 1000 kg 15 % H_2o  Dried Product 99.5 % solid Weight of solid in feed = 1000*0.85 = 850 kg Weight of water in feed = 150 kg Let, weight of dried producy = x kg	1 1 1	8

	It contain 99.5 % solid and solid is unchanging component. ∴ **solid balance ,** 0.995 x = 850 x = 850/0.995 x = 854.27 kg ∴ weight of water in dried product = 854.27 – 850 = 4.27 kg Water removed in dryer = 150 – 4.27 = 145.73 kg ∴ original water removed = $\frac{145.73}{150}$ x 100 **= 97.15 % ……………………….Ans.**	1 1 1 1 1	
4-c	**SOLUTION :** **BASIS :** 100 kmol of SO_2 $SO_2 + ½ O_2 \longrightarrow SO_3$ ∴ 1 kmol of SO_2 ≡ ½ kmol O_2 ∴ kmol O_2 required = 100 * 0.5 = 50 kmol ∴ O_2 supplied = 50*1.8 = 90 kmol N_2 supplied = $\frac{79}{21}$ x 90 = 338.57 kmol SO_2 reacted = 100 x 0.70 = 70 kmol O_2 required = 70 x 0.5 = 35 kmol SO_3 formed = 70 kmol **Composition of gases leaving reactor :-**	1 1 1 1 1 1 1	8

	<table><tr><th>Product</th><th>Quantity,Kmol</th><th>Mole %</th></tr><tr><td>SO_2</td><td>100 – 70 = 30</td><td>6.07</td></tr><tr><td>O_2</td><td>90 – 35 = 55</td><td>11.14</td></tr><tr><td>N_2</td><td>338.57</td><td>68.6</td></tr><tr><td>SO_3</td><td>70</td><td>14.18</td></tr><tr><td>Total</td><td>493.57</td><td></td></tr></table>	1	
5	Any 2		16
5-a	**Basis: 100 kg gas** Avg mol wt of gas = 30 *0.65 +58*0.35=39.8 Total moles= 100/39.8 = 2.512 kmoles Kmoles of ethane= 1.6328 Kmoles of butane= 0.879 Reactions are: C_2H_6+ 7/2 O_2 $\longrightarrow$ $2CO_2 + 3H_2O$ C_4H_{10}+ 13/2 O_2 $\longrightarrow$ $4CO_2 + 5_2O$ Oxygen theoretically required = 7/2*1.16328 + 13/2 * 0.879 = 11.42 O_2 fed = 11.42 + 0.2*11.42 = 13.704 kmoles O_2 unreacted = 13.704 – 11.42= 2.284kmoles N_2 fed= 51.54 kmoles CO_2 formed = 3.27 + 3.516 = 6.786 kmoles H_2O formed = 4.898 + 4.395 = 9.293 kmoles Weight of gas = 2.284* 32 + 51.54*28+ 6.786*44+9.293*18 = **1981.87 Kg**	 1 1 1 1 1 1 1 1	8

5-b	**Case –I: Basis:** 100 Kg/hr of solid handling capacity of the evaporator.		8

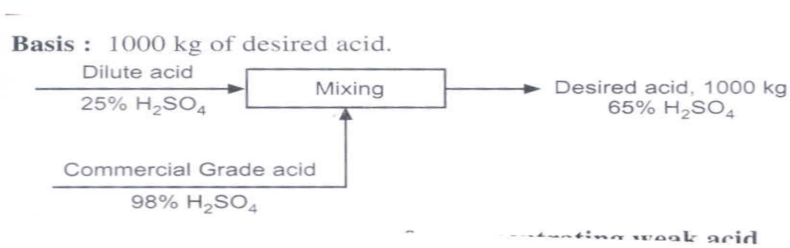


(1)

	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 :		
	$0.04\ A = 0.35\ B$		
	$A = 8.75\ B$		
	Putting in above equation	1	

	$8.75\,B = B + 1800$ $B = 232.26$ 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 ethylene gas $C_2H_4(g) + \frac{1}{2} O_2 \longrightarrow C_2H_4O(g)$ ΔH^o_R = Standard heat of reaction $= [\Sigma \Delta H^o_c]$ product - $[\Sigma \Delta H^o_c]$ reactant $= [1 \times \Delta H^o_c)\ C_2H_4O(g)\ ] - [1 \times \Delta H^o_c\ C_2H_4(g) + 1 \times \Delta H^o_c\ O_2]$ $= [1 \times (-12.58)] - [1 \times (12.50) + 1/2 \times (0.0)]$ $= -12.58 - 12.50$ $= -25.08$ KJ per mol $C_2H_4O(g)$ produced. Change in the enthalpy for 5 mol $C_2H_4O(g)$ produced = -25.08 X 5 = **-125.40 KJ ------Ans**	2 3 3	8
6	**Any 4**		16
6-a	**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 . For example, the stoichiometric equation $CO + H_2 \longrightarrow CH_3OH$ Indicates that one molecule of CO react with two molecules of hydrogen to	2	4

	produce one molecule of methanol **2) Stoichiometric Coefficient :** It is the number that precedes the formula of each component involved in a chemical reaction. For example, the stoichiometric equation $CO + H_2$------→ CH_3OH In above example Stoichiometric Coefficient of CO is one, Stoichiometric Coefficient of H_2 is Two and Stoichiometric Coefficient of methanol is one **(Students may write other suitable example)**	2	
6-b	**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 = $\frac{\text{Oil recovered}}{\text{Oil in Seeds}}$ * 100	1 1 1	4

	% recovery of Oil = $\frac{42.19}{45} * 100$ **% recovery of Oil = 93.75% ----------- ans.**	1	
6-c	**Basis :**1000 Kg of desired acid  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 X + Y = 1000 -------------(1) **Material Balance of H_2SO_4** H_2SO_4 in dilute acid + H_2SO_4 in Commercial Grade = H_2SO_4 in desired acid 0.25 X +0.98 Y = 0.65 * 1000	1	4

	$0.25X + 0.98Y = 650$ $Y = \dfrac{650 - 0.25X}{0.98}$ 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**	1 1 1	
6-d	**Basis:** 50 kmol of butane fed to combustion reactor Reaction, $C_4H_{10} + 13/2\ O_2 \text{----}\rightarrow 4CO_2 + 5H_2O$ From reaction, 1 Kmol of C_4H_{10} =6.5 kmol O_2	1	4

	50 Kmol of C_4H_{10} = (50*6.5)/1 Kmol O_2 = 325 Kmol O_2 required Theoretical O_2 required = 325 Kmol % Excess O_2 = 35 % Actual O_2 fed = Theoretical O_2 required [1+ % Excess /100] Actual O_2 fed = Theoretical O_2 required [1+ 35 /100] Actual O_2 fed = 325* [1+ 35 /100] Actual O_2 fed = **438.75 kmol ---------------Ans.**	 1 1 1	
6-e	**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 From reaction 2 kmol A = 1 kmol B = 1 kmol C B reacted = (1/2)* X = 0.5 X kmol C formed = (1/2)* X = 0.5 X kmol Material Balance of A give A unreacted = (60 – X) kmol **Material Balance of Inerts :** Inerts in feed = Inert in product = 10 kmol C formed = (1/2)* X = 0.5 X kmol B unreacted = (30 - 0.5 X) kmol Total moles of product stream = (60-X) + (30-0.5X) + 10=0.5X = 100 –X Kmol Mole % of A in product stream = 2% Kmol A in product stream Mole % of A = ------------------------------------ * 100	 1 1	4

	Total kmol of product stream $$2 = \frac{60 - X}{100 - X} * 100$$ X = 59.184 kmol = amount of A reacted $$\text{Conversion of A} = \frac{\text{Kmol A reacted}}{\text{Total kmol of A feed}} * 100$$ $$\text{Conversion of A} = \frac{59.184}{60} * 100$$ = **98.64 % ------ Ans**	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. **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.	2 2	4