MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER-16 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.

SUMMER-16 EXAMINATION
Model Answer

Q No.	Answer	marks	Total marks
1-A	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 **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-b	**Limiting reactant**: It is the component or reactant which gets over first in a chemical reaction or it is the reactant which decides the extent of a reaction or it is the reactant which is added in limited quantity. **Excess reactant:** It is the reactant which is in excess of the theoretical or stoichiometric requirement.	1 1	2
1A-c	**Ideal Gas law:** PV=nRT where P - pressure, V - volume, n- moles, K-absolute temperature and R – universal gas constant	2	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. $P_A = P^0_A X_A$ **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	1 1	2

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER-16 EXAMINATION
Model Answer

Subject code :(17315)

Page **3** of **23**

	equilibrium above the liquid surface.		
1 A-e	**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 ΔT1 B $\longrightarrow$ C ΔT2 C $\longrightarrow$ D ΔT3 A $\longrightarrow$ D ΔT Then ΔT = ΔT1 +ΔT2+ ΔT3	2	2
1A-f	**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 Coefficient :** It is the number that precedes the formula of each component involved in a chemical reaction.	1 1	2
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 2 1 2	6
1B-b	Basis: 0.577 mol fr of acetone in.the mixture Mol fr. of butane = 1-0.577 = 0.423 Partial pr of butane = 698 mm Hg Applying Raoults law to butane Partial pr = Mol fr * vapour pr	 2 2	6

SUMMER-16 EXAMINATION
Model Answer

	Vapour pressure = Partial pressure/ mol fr $\quad\quad\quad\quad$ = 698/0.423 $\quad\quad\quad\quad$ = 1650 mm Hg	2	
1B-c	**Basis :** Gas mixture containing 0.274 kmol HCl,0.337 kmol N_2,0.089 kmol O_2. Total moles of the gas mixture = 0.274 +0.337 +0.089 = 0.7 kmol Mole fraction of HCl (X_{HCl}) = 0.274/0.7 = 0.399 Mole fraction of N_2 (X_{N2}) = 0.337/0.7 = 0.481 Mole fraction of O_2 (X_{O2}) = 0.089/0.7 = 0.127 (i)Volume occupied by this mixture T =303 K$\quad$P= 405.3 kPa $$PV = nRT$$ $$\therefore V = \frac{nRT}{P}$$ $$= \frac{0.7 \times 8.3145 \times 303}{405.3}$$ $$= \textbf{4.35 m}^3$$	1 1 1 1	6

SUMMER-16 EXAMINATION
Model Answer

	(ii) Average molecular weight of the Gaseous mixture		
	$M_{avg} = \Sigma M_i X_i$	1	
	$= M_{HCl} . X_{HCl} + M_{N2} . X_{N2} + M_{O2} . X_{O2}$		
	$= 36.5 \times 0.391 + 28 \times 0.481 + 32 \times 0.127$	1	
	$\therefore M_{avg} =$ **31.80**		
2	Any 4		16
2-a	**Steps involved in solving material balance calculations:**	½ mark each	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 algebric equations		
	8. Get values of two unknown quantities.		
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.	1	4
	Reasons for performing recycling: (any four)	¾ marks each for any 4	
	1. Maximum utilization of the valuable reactant		
	2. Improvement of the performance of the equipment/ operation		
	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		

SUMMER-16 EXAMINATION
Model Answer

	6. Enrichment of a poduct		

2-c	**Basis :** 100 Kmol of feed		4
	Feed contains 60 kmol A , 30 kmol B and 10 kmol inerts		
	Let X be the kmol of A reacted by reaction :	1	
	$\qquad$ 2A + B ----- C		
	From reaction 2 kmol A = 1 kmol B = 1 kmol C		
	$\qquad$ B reacted = (1/2)* X = 0.5 X kmol		
	$\qquad$ C formed = (1/2)* X = 0.5 X kmol		
	Material Balance of A give		
	$\qquad$ A unreacted = (60 – X) kmol		
	Material Balance of Inerts :		
	$\qquad$ Inerts in feed = Inert in product = 10 kmol		
	$\qquad$ C formed = (1/2)* X = 0.5 X kmol		
	$\qquad$ B unreacted = (30 - 0.5 X) kmol		
	Total moles of product stream = (60-X) + (30-0.5X) + 10=0.5X		
	$\qquad$ = 100 –X Kmol	1	
	Mole % of A in product stream = 2%		
	$\qquad$ Kmol A in product stream		
	Mole % of A = ---------------------------------- * 100		
	$\qquad$ Total kmol of product stream		
	$\qquad$ 2 = (60 – X)100/(100-X)		
	$\qquad$ X = 59.184 kmol = amount of A reacted	1	

	Kmol A reacted Conversion of A = ------------------------------------ * 100 Total kmol of A feed 59.184 Conversion of A = --------- * 100 = **98.64 %** ------ Ans 60	1	

2-d

SOLUTION :

BASIS : 10 kmol of SO_2 fed

$SO_2 + \frac{1}{2} O_2 \longrightarrow SO_3$

O_2 supplied = 10 kmol

N_2 supplied = $\frac{79}{21}$ x 10

    = 37.62 kmol

Conversion of SO_2 = 80%

SO_2 reacted = 10 x 0.80

        = 8 kmol

O_2 reacted = 8 x 0.5

        = 4 kmol

SO_3 formed = 8 kmol

Composition of gases leaving reactor :-

Product	Quantity,Kmol	Mole %
SO_2	10 – 8 = 2	3.73
O_2	10 – 4 = 6	11.18
N_2	37.62	70.16
SO_3	8	14.92

(Marks for 2-d: 4 total — 1, 1, 2)

SUMMER-16 EXAMINATION

Model Answer

		Total	53.62				
2-e	Basis: 100 k mol SO_2 fed $C_2H_4 + \frac{1}{2} O_2 \dashrightarrow C_2H_4O$ Theoretical O_2 required = 100*0.5 =50 kmol % excess O_2 is 20 O_2 fed = 50 + 0.2*50 =60 kmol Air fed = 60 * 100/ 21= 285.71 kmol $\quad$ = 285.71*28.84 $\quad$ = **8240 Kg**					1 1 1 1	4
2-f	$C_p = 21.3655 + 64.2841*10^{-3}T – 41.0506*10^{-6} + 9.7999*10^{-9}$ T1= 298K T2 = 383K $Q = 100[21.3655(383-298) + 64.2841*10^{-3}/2(383^2-298^2) - 41.0506*$ $\quad 10^{-6}/3(383^3- 298^3) +9.7999*10^{-9}/4(383^4-298^4)$ $\quad$ = **330336 KJ/min**					1 2 1	4
3	Any 2						16
3-a	**Solution :Basis:** 100kg of product gases leaving the oxidizer **Reaction:** $4 HCl + O_2 \rightarrow 2 Cl_2 + 2 H_2O$ Product gases contain 13.2 kg HCl, 6.3 kg O_2, 42.9kg N_2, 30 kg Cl_2 and 7.6 kg H_2O. Quantity of HCl unreacted = HCl in product gases = 13.2 kg Cl_2 produced = Cl_2 in product gases = 30kg					01	8
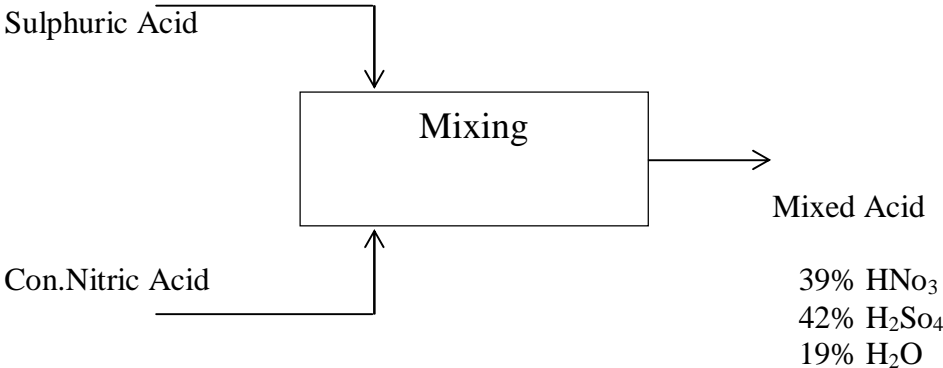
We have from the reaction, 4 kmolHCl = 2 kmol Cl_2
i.e., 146 kg HCl = 142 kg Cl_2 (on weight basis)

∴ Quantity of HCl reacted to produce 30 kg Cl_2

$= \frac{146}{142} \times 30 = 30.85$ kg   01

Material balance of HCl:
HCl charged = HCl reacted + HCl unreached

∴HCl charged = 30.85 + 13.2 = 44.05 kg

Moles of HCl Charged $= \frac{44.05}{36.5} = 1.2068$ kmol

We have, 4 kmolHCl = 1 knol O_2 …. Mole basis

∴146 kg HCl = 32 kg O_2 …. Weight basis

∴Quantity of O2 reacted with 30.85 kg HCl $= \frac{32}{146} \times 30.85 = 6.76$ kg   01

Material balance of O₂:
O_2 charged = O_2 reacted + O_2 unreacted

= 6.76 + 6.3 = 13.06 kg

N_2 charged = N_2 in product gaes = 42.9 kg

∴Air charged = (O_2 + N_2) in air charged

= 13.06 + 42.9 = 55.96 kg
Mol. Wt. of air = 28.84

Moles of air charged or supplied $= \frac{55.96}{28.84} = 1.94$ kmol   01

Theoretical O_2 required for 1.2068 kmolHCl charged, form the reaction

$= \frac{1}{4} \times 1.2068 = 0.3017$ kmol

                                                                                                                                   01

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER-16 EXAMINATION
Model Answer

Subject code :(17315)   Page **10** of **23**

Theoretical air required $= 0.3017 \times \frac{100}{21} = 1.44$ kmol

% excess air $= \frac{\text{air supplied} - \text{air theoretically required}}{\text{air theoretically required}} \times 100$

$= \frac{1.94 - 1.44}{1.44} \times 100 = 34.72$ **...... Ans. (a)**

01

Composition of Gases Entering the Reactor :

Component	Quantity in kg	Weight
HCl	44.05	44.05
O_2	13.06	13.06
N_2	42.90	42.90
Total	100.00	100.00

……. Ans. (b)

01

The degree of completion of oxidation is nothing but the percent conversion of hydrochloric acid gas (limiting reactant).

$\therefore$ Degree of completion of oxidation $= \frac{30.85}{44.05} \times 100 = \textbf{70\%}$ **……. Ans. (C)**

01

i.e., Oxidation is 70% complete.

3-b   .Basis – 100kg of mixed acid   8

Sulphuric Acid

Mixing

Mixed Acid

Con.Nitric Acid

39% HNO_3
42% H_2SO_4
19% H_2O

Acl 'x' kg of nitric acid & 'y' kg of H_2SO_4 68.3

1

SUMMER-16 EXAMINATION
Model Answer

	$\therefore$ Overall balance	1	
	x+ y = 100	1	
	Material balance of Nitric acid		
	0.683x = 39		
	$\therefore x = \frac{39}{0.683}$		
	Weight of HNO_3 = 57.1	1	
	$\therefore$ Weight of H_2SO_4 = 100 – 57.1		
	$\qquad$ = 42.9 kg	1	
	Strength of H_2So_4		
	0.429y = 42		
	$\therefore y = \frac{42}{0.429}$	1	
	$\quad$ = 97.9		
	Weigth ratio of $HNo_3 = \frac{Kg \text{ of } HNO_3}{Kg \text{ of } H_2So_4}$		
	$\qquad = \frac{57.1}{42.9}$		
	$\qquad = 1.33$	2	
3-c	Basis : 1000 kmol Benzen- Toluene mixture	1	8

SUMMER-16 EXAMINATION
Model Answer

	Let X and Y be the mass flow rates of distillate and bottom product respectively		
	Overall Material Balance:	1	
	$X + Y = 1000$ ------- (i)		
	Material Balance of benzene:		
	$(52/100)*X + (5/100)*Y = (28/100)*1000$		
	$0.52*X + 0.05*Y = 280$		
	By solving **X = 489.36 Kg/hr** **Y = 510.64 kg/hr**	2	
	Mass flow rates of distillate = **489.36 Kg/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**	2	
	% recovery of benzene = $\dfrac{\text{benzene in distillate}}{\text{Benzene in feed}}$ * 100		
	% recovery of benzene = $\dfrac{254.47}{280}$ * 100	2	
	% recovery of benzene = 90.88 % -------- ans. (b)		
4	Any 2		16
4-a	**Solution: Basis:** 3 mol $CaSO_4$ reacted.	1	8

SUMMER-16 EXAMINATION

Model Answer

	$3CaSO_4(S) + 3SiO_2(S) \rightarrow 3CaO.SiO_2(S) + 3SO_2(g) + 3O_2(g)$
	
	 The standard heat of reaction at 298 K is given by the relation
	
	 The given reaction is not balanced . Based on the given equation the problem is solved as below.
	
	 Heat of reaction is = [sum of heat of formation of products]– [sum of heat of formation of reactants.]
	
	        = 3(-2879)+ 3(-296.81) –[3(-1432.7)+3(-903.5)]
	
	        = -2518.83 KJ
	
	 Due consideration should be given for any other solution also.
		4
		
		 3	

4-b	**Solution: Basis:** 100 kg of wet solids. Solids in the feed = $0.08 \times 100 = 80$ kg Water in the feed = $0.2 \times 100 = 20$ kg Water removed = $0.8 \times 20 = 16$ kg Water in solids leaving the dryer = $20 - 16 = 4$ kg $\therefore$ wet solids leaving the dryer = $80 + 4 = 84$ kg $\therefore$ mass fraction of dry solids in the wet solids leaving the dryer $= \frac{80}{84} = $ **0.9523** **…. Ans. (a)** Weight ratio of water removed to wet solids leaving the dryer $= \frac{16}{84} = $ **0.19 : 1** **….. Ans. (b)** Additional water to be removed to dry the 100 kg wet solids completely = 4 kg	01 01 02 02	8

SUMMER-16 EXAMINATION
Model Answer

	$\therefore$ Additional water to be removed to dry completely 1000 kg/day wet solids $= \frac{4}{100} \times 1000 =$ **40 kg** **…..Ans. (c)** This is in addition to $\frac{16}{100} \times 1000 = 160$ kg water removed.	02	
4-c	**Solution: Basis:** 3000 kg of monochloroacetic acid production per batch. Mol. Wt. of CH2ClCOOH = 94.5 Moles of CH2ClCOOH produced per batch $= \frac{3000}{94.5} = 31.75$ kmol **Reaction:** $CH_3COOH + Cl_2 \rightarrow CH_2ClCOOH + HCl$ From the reaction, 1kmol $CH_2ClCOOH \equiv 1$ kmol $CH_2ClCOOH$ i.e., for producing 1 kmol $CH_2ClCOOH$, 1 kmol acetic acid is consumed. CH_3COOH reacted for 31.75 kmol $CH_2ClCOOH$ production $= 31.75 \times \frac{1}{1} = 31.75$ kmol Given : The reaction is 95% complete, i.e., conversion of acetic acid is 95%. $\therefore CH_3COOH$ charged $= \frac{CH_3COOH \text{ reacted } \times 100}{\% \text{ conversion}}$ $= \frac{31.75}{0.95} = 33.42$ kmol From the reaction, 1 kmol $CH_3COOH \equiv 1$ kmol Cl_2 i.e., for 1 kmol CH_3 COOH, theoretical Cl_2 required is 1 kmol. Therefore,	01 01 01	8

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER-16 EXAMINATION
Model Answer

Subject code :(17315)   Page **15** of **23**

	Theoretical requirement of Cl_2	01	
	For 33.42 kmol $CH_3COOH = \frac{1}{1} \times 33.42 = 33.42$ kmol		
	Given : 15% excess Cl_2 is used. Therefore,	01	
	Cl_2 fed/supplied $= 33.42 \times (1 + \frac{15}{100}) = 38.43$ kmol	01	
		01	
	$\therefore$ Amount of Cl_2 required per batch $= 38.43 \times 71 = $ **2728.5 kg**		
	Amount of CH_3COOH required per batch $= 33.42 \times 60 = $ **2005.5 kg**	01	
5	Any 2		16
5-a	**Attempt any TWO of the following**		8
	Basis : 100 mol of gas burnt	01 mark	
	It contain 25 mol CO, 5 mol CO_2, 2 mol O_2 and 68 mol N_2		
	$CO + ½ O_2 \longrightarrow CO_2$	01 mark	
	1 mol CO $\equiv$ 0.5 mol O_2		
	Theoretical O_2 requirement $= (0.5/1) \times 25 = 12.5$ mol		
	25 % excess air is used ,	01 mark	
	O_2 in air supplied $= 1.25 \times 12.5 = 15.625$ mol		
	N_2 in supplied air $=(79/21) \times 13.125 = 58.78$ mol		
	CO reacted $=0.9 \times 25 = 22.5$ mol	01 mark	
	CO unreacted $= 25-22.5=2.5$ mol		
	CO_2 produced $= 22.5$ mol	01 mark	
	Total CO_2 in gas leaving $= 22.5 + 5 =27.5$ mol		
	O_2 reacted $=(1/2) \times 22.5 = 11.25$ mol	01 mark	
	O_2 unreacted $= 15.625-11.25 = 4.375$ mol		

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER-16 EXAMINATION
Model Answer

Subject code :(17315)

Page **16** of **23**

Total O_2= 4.375+ 2= 6.375 mol			01 mark
N_2 in leaving gas =58.78 + 68 = 126.78 mol			

Analysis of flue gases :

Component	Quantity	Mole %
CO_2	27.5	16.86
O_2	6.375	3.91
N_2	126.78	77.71
CO	2.5	1.5
Total	151.75	100.00

01 mark

5-b	**Basis :** 15000 Kg/hr of weak solution fed to evaporator	1

8

Let X,Y and Z be the kg/h of water evaporated ,thick liquor and NaCl
precipitated as crystal

Overall Material Balance :

$15000 = X + Y$ --------(1)   1

Material balance of NaOH

NaOH in feed solution = NaOH in thick Liquor   1

$0.15 \times 15000 = 045 Y$ -------------(2)

Material balance of NaCl   1

Nacl in feed solution = NaCl in thick liquor + Nacl crystal obtained

$0.10 \times 15000 = 0.02 \times 5000 + Z$

Z = 1400 kg /hr

Put X and Y in equation (1)   1

$X + 5000 + 1400 = 15000$

X = 8600 kg/hr   1

Water evaporated = 8600 kg/hr

Thick liquor obtained = 5000 kg/hr   2

	NaCl precipitated as Crystal = 1400 kg/hr		
5-c	**Basis :** 1 kmol SO_2 reacted $SO_2 + \frac{1}{2} O_2 ---\rightarrow SO_3$ ΔH^O_R = Heat of reaction at 298 .15 K $\quad\quad$ = 1 x (-395720) - 1 x (-296810) $\quad\quad$ = - 98910 KJ/ kmol The standard heat of reaction at any temperature T is given by $\Delta H^O_{RT} = \Delta H_o + \Delta a \, T + (\Delta b/2) \, T^2 + (\Delta c/3) \, T^3 + (\Delta d/4) \, T^4$ Δa = [1 x 22.036] – [1 x 24.771 + 1/2 x (26.026)] = - 15.748 Δb = [1 x 121.624] x 10^{-3} – [1 x 62.948 + ½ x 11.755] $\quad$ = 52.799 x 10^{-3} Δc = [1 x – 91.867] x 10^{-6} **–** [1 x -44.258 + ½ x -2.343] x 10^{-6} $\quad\quad$ = - 46.438 x 10^{-6} Δd = [1 x 24.36] x 10^{-9} – [1 x 11.122 + 1\2 x – 0.562] x 10^{-9} $\quad\quad$ = 13.528 x 10^{-9} $\Delta H^O_{RT} = \Delta H_o$ -15.748 T + (52.799 x 10^{-3}/2 T^2) $\quad\quad\quad$ - (46.438 x 10^{-6}/3 T^3) + (13.528 x 10^{-9}/ 4 T^4) $\quad$ = ΔH_o – 15.748 T + 26.3995 x 10^{-3} T^2 – 15.4793 x 10^{-6} T^3 $\quad\quad$ + 3.382 x 10^{-9} T^4 (-98910) = ΔH_o – 15.748 x 298 + 26.3995 x 10^{-3} x 298^2 $\quad\quad\quad$ – 15.4793 x 10^{-6} x 298^3 + 3.382 x 10^{-9} x 298^4 (-98910) = ΔH_o – 4693 + 2344 + -410 + 27		2 2	8

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION

(Autonomous)

(ISO/IEC - 27001 - 2005 Certified)

SUMMER-16 EXAMINATION

Model Answer

Subject code :(17315)

Page **18** of **23**

	$\Delta H_o = -96178$	2	
	ΔH^O_{RT} = Standard heat of reaction at temperature T		
	The expression relating the standard heat of reaction and the temperature of the reaction is		
	$\Delta H^O_{RT} = -96178 - 15.748\,T + 26.3995 \times 10^{-3}\,T^2$ $- 15.4793 \times 10^{-6}\,T^3 + 3.382 \times 10^{-9}\,T^4$		
	Putting $T = 773\,^oK$		
	$\Delta H^O_{RT} = -96178 - 15.748 \times 773 + 26.3995 \times 10^{-3} \times 773^2$ $- 15.4793 \times 10^{-6} \times 773^3 + 3.382 \times 10^{-9} \times 773^4$	2	
	$\mathbf{\Delta H^O_{RT} = -98.519\ kJ / mol}$		
6	**Any 4**		16
6-a	**Basis :** 50 kmol /hr of butane		4
	$C_4H_{10} + 13/2\ O_2 \longrightarrow 4CO_2 + 5H_2O$	1	
	Air flow rate = 2100 kmol/hr		
	O_2 in air supplied = 2100 x 0.21 = 441 kmol/hr		
	From reaction ,we have	1	
	1 kmol $C_4H_{10} \equiv 6.5$ kmol O_2		
	Theoretical O_2 requirement = 6.5/1 x 50 = 325 kmol		
	Theoretical requirement of air = 325 x (100/ 21)		
	= 1547.6 kmol/hr		
	Air supplied to reactor = 2100 kmol /hr	1	
	% excess air = $\dfrac{(\text{Air Supplied} - \text{Theoretical requirement of air})}{\text{Theoretical requirement of air}} \times 100$		
	(2100 – 1547.6)		

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION
(Autonomous)
(ISO/IEC - 27001 - 2005 Certified)

SUMMER-16 EXAMINATION
Model Answer

Subject code :(17315)   Page **19** of **23**

	% excess air = ---------------------------- x 100 $\qquad$ 1547.6 **% excess air = 35.7 %**	1	
6-b	**Basis:** 100 kg feed to extractor Pyridine in feed $= 0.27 \times 100 = 27$ kg Water in feed $= 0.73 \times 100 = 73$ kg Let X,Y,and Z be the quantities of extract phase ,raffinate phase and solvent required **Overall material balance** Feed + Solvent = Extract phase + Raffinate phase $100 + Z = X + Y$ ------------(1) **Material balance of Pyridine :** $0.11 X + 0.05 Y = 27$ ----------------(2) **Material balance of Water :** $0.009 X + 0.95 Y = 73$ ---------------(3) Solving equation (2) and (3) $X = 211.4$ kg and $Y = 74.84$ kg Quantity of extract phase (layer) $= 211.4$ kg Quantity of raffinate phase $= 74.84$ kg Put the value of X and Y in equation (1) $100 + Z = 211.4 + 74.84$ $Z = 186.24$ Kg Solvent (Chlorobenzene) required $= 186.24$ kg	1 1 1	4

SUMMER-16 EXAMINATION
Model Answer

		1	
	Weight ratio of solvent to feed = $\dfrac{186.24}{100}$ = **1.862**		

6-c	**Basis :** Solution at 298 K		4
	Let 'X' be the kg of solution after crystallization		
	Molecular weight of $CaCl_2$ = 111		
	Molecular weight of $CaCl_2.6H_2O$ = 219	1	
	Molecular weight of $6H_2O$ = 108		
	Let 'Y' be the kg of final solution at 298 K		
	Material Balance for $CaCl_2$:		
	$(60/100) X + (111/219) (200) = (819.2/1819.2) Y$		
	$0.625 X + 101.36 = 0.45 Y$	1	
	Material Balance for H_2O:		
	$(100/160) X + (108/219) (200) = (1000/ 1819.2) Y$		
	$0.625 X + 98.63 = 0.55 Y$	1	
	$Y = (0.625 X +98.63) / 0.55$		
	Put the value of Y from equation (2) in equation (1)		
	$0.375 X + 101.36 = (0.45/ 0.55) (0.625 X + 90.63)$		
	$0.1363 X = 20.67$		
	$X = 151.6 kg$	1	
	Amount of Solution necessary = 151.6 kg		

SUMMER-16 EXAMINATION

Model Answer

6-d	**Basis :** 1 Kg of hydrochloric acid gas charged		4
	Reaction : $4HCl + O_2$ -----$\rightarrow$ $2Cl_2 + 2H_2O$	1	
	Moles of acid charged = 1/ 36.5 = 0.0274 kmol		
	From reaction, we have		
	4 kmol HCl $\equiv$ 1 kmol O_2		
	O_2 theoretically required for oxidation of 0.0274 kmol acid		
	= (1/4) 0.0274 =0.00685 kmol		
	Air is used 30% in excess of that theoretical requirement		
	O_2 in supplied air = Theoretically required $O_2[1 + \%$ excess/100]	1	
	= 0.00685 [1 + (30/100)] = 0.0089 kmol		
	Air contains 21 % by volume		
	Air supplied = 0.0089 X (100/20) = 0.0424 kmol	1	
	Molecular weight of air = 28.84		
	Air supplied per kg of acid = kmol air X Mol. weight of air		
	= 0.0424 X 28.84	1	
	= 1.22 kg of air per kg of acid		
6-e	**Basis :** 100 kmol/hr acetaldehyde charged to reactor		4
	Reaction :	1	
	$CH_3CHO + ½ O_2$ --------$\rightarrow$ CH_3COOH		

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SUMMER-16 EXAMINATION

Model Answer

Subject code :(17315)

Page **22** of **23**

	Let X be the kmol of product obtained per hour Acetic acid formed = 0.5926 X kmol/hr Acetaldehyde unreacted = 0.1481 X kmol hr From reaction , 1 kmol CH_3CHO ≡ 1 kmol CH_3COOH Acetaldehyde reacted to produce acetic acid = 0.5926 X x (1/1) = 05926 X kmol/hr **Material balance of CH_3CHO** CH_3CHO fed to reactor = CH_3CHO reacted+CH_3CHO unreacted 100 = 0.5926 X + 0.1481 X **X = 135 kmol /hr** Acetaldehyde reacted = 0.5926 (135) = 80 kmol/hr **% conversion of CH_3CHO = (80/100) x 100 = 80 %**	1 1 1	
6-f	**Basis :** 1 mol of benzoic acid crystal 1. $C(s) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H_1 = - 393.51$ KJ/mol 2. $H_2(g) + 1/2\ O_2(g) \longrightarrow H_2O(l)$ $\Delta H_1 = - 285.83$ KJ/mol 3. $C_7H_6O_2(c) + 7.5\ O_2(g) \longrightarrow 7CO_2(g) + 3\ H_2O(l)$ $\Delta H^0c = - 3226.25$ KJ/mol 4. $7C(s) + 3\ H_2(g) + O_2(g) \longrightarrow C_7H_6O_2(g)$	1 1	4

SUMMER-16 EXAMINATION
Model Answer

$\Delta H^0 f = $? $\Delta H^0 f = $ Standard heat of formation of benzoic acid crystal Reaction(4) = 7 x Reaction (1) + 3x Reaction (2) – Reaction (3) $\Delta H^0 f = 7 \times \Delta H_1 + 3 \times \Delta H_2 - \Delta H^0 c$ = 7 x (-393.51) +3 x (-285.83) – (-3226.25**)** = (-787.02) + (-857.49) – (- 3226.25) = **-**385.11 KJ/mol $\Delta H^0 f$ = **-385.11 KJ/mol ------- ans.**	1 1	