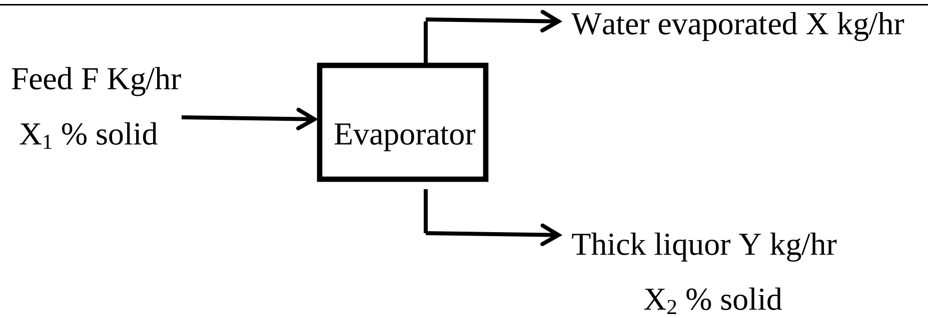
WINTER-19 EXAMINATION

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	Sub q.no.	Answer	marks
	1	**Any 5**	**10**
1	a	Given: Pressure = 800 mm Hg 760 mm Hg= 101.325 kPa 800 mm hg = **106.66 kPa** 760 mm Hg= 14.7 psi 800 mm hg = **15.47 psi**	 1 1
1	b	**Raoult'slaw:**It states that at a given temperature, the equilibrium partial pressure of a component of a solution in the vapour is equal to the product of the mole fraction of the component in the liquid phase and the vapour pressure of the pure component. $p_A = P_A.x_A$ **Ideal gas equation is** PV=nRT Where P= pressure V=Volume n= number of moles R= Universal gas constant T= absolute temperature	1 1

<table>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td>c</td><td>

Block diagram of evaporation</td><td>2</td></tr>
<tr><td>1</td><td>d</td><td>Stoichiometric coefficient
CO = 1
H_2 = 2
CH_3OH = 1
Weight ratio of CO to H_2 = 28/4 = 7</td><td>1

1</td></tr>
<tr><td>1</td><td>e</td><td>Net Calorific value(NCV): It is the calorific value of the fuel when the water in the combustion products is present in vapour form .</td><td>2</td></tr>
<tr><td>1</td><td>f</td><td>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:It is the heat required to change the phase of a substance at constant temperature and pressure.</td><td>1

1</td></tr>
<tr><td>1</td><td>g</td><td>Force : A push or a pull is called force. It is the product of force and acceleration
F=M*a
SI unit of force is Newton.</td><td>1

1</td></tr>
<tr><td>2</td><td></td><td>Any 3</td><td>12</td></tr>
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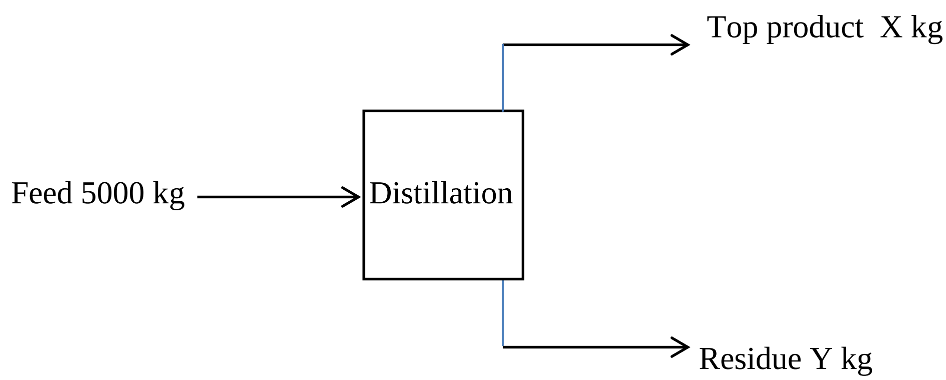
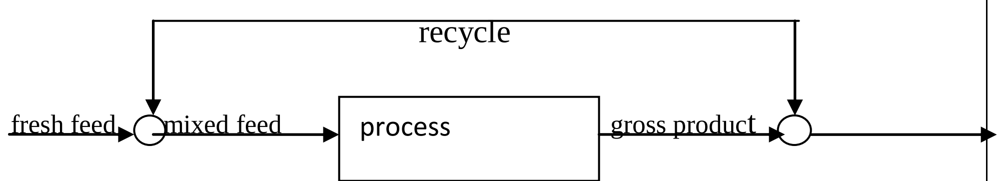
2	a	Basis : 5000 kmol Benzen- Toluene mixture	
			1
		Let X and Y be the mass flow rates of distillate and bottom product respectively	
		Overall Material Balance:	1
		X + Y = 5000 ------- (i)	
		Material Balance of benzene:	
		(30/100)*X + (10/100)*Y = (40/100)*5000	
		0.3*X + 0.1*Y = 2000	1
		By solving **X =7500 kg/hr**	
		Y= -2500 kg/hr	1
		Mass flow rates of distillate = **7500 kg/hr** ---- ans. (a)	
		Mass flow rates of bottom Product = **-2500 kg/hr** ---- ans.(a)	
		Note: The answer is coming in negative.	

2 b

Recycling: It is returning back a portion of stream leaving a process unit to the entranc process unit for further processing. 2

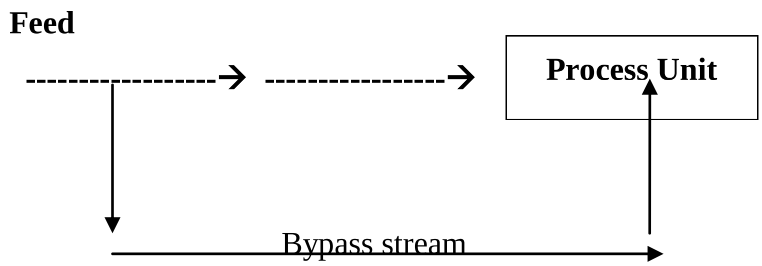
Reasons for performing recycling: (any four)

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



Bypass Operation :

In these operations, a fraction of the feed stream to a process unit is diverted around and co with the output stream. 2



- Bypassing is practiced industrially whenever accurate control of the composition or conce

		of the process exit stream is expected. - The composition and properties of the product may be varied by varying the fraction of the that is bypassed.	
2	c	Basis – 10kmol SO_2 100 kmol air Reaction $SO_2 + \frac{1}{2}O_2 = SO_3$ Air fed = 100kmol O_2 in air = 100 × (0.21) = 21 kmol Theorctical requirement of O_2 1 Kmol SO_2 ≡ 0.5 kmol O_2 $= \frac{0.5}{1} \times 10$ = 5 kmol	1 1

		$\therefore$% excess of O_2 used $= \frac{O_2 \text{ in supplied} - O_2 \text{ theo read}}{O_2 \text{theo read}}$ $= \frac{21-5}{5} \times 100$ = 320 $\therefore$ % excess air used = **320%**	1 1
2	d	**Basis :** 1 mol of benzoic acid crystal 1. $C(s) + O_2(g)$ ------> $CO_2(g)$ ΔH_1 = - 393.51 KJ/mol 2. H_2 (g) +1/2 O_2(g) ------> H_2O(l) ΔH_1 = - 285.83 KJ/mol 3.$C_7 H_6O_2$ (c) + 7.5 O_2(g) ------> $7CO_2$(g) + 3 H_2O(l) ΔH^0c = - 3226.25 KJ/mol 4. 7C(s) + 3 H_2 (g) + O_2(g) ------> C7 H_6O_2 (g) ΔH^0f = ? ΔH^0f = Standard heat of formation of benzoic acid crystal Reaction(4) = 7 x Reaction (1) + 3x Reaction (2) – Reaction (3) $\Delta H^0f = 7 \times \Delta H_1 + 3 \times \Delta H_2 - \Delta H^0c$ = 7 x (-393.51) +3 x (-285.83) – (-3226.25) = (-2754.57) + (-857.49) – (- 3226.25) = -385.11 KJ/mol 3612.06 **ΔH^0f = -385.11 KJ/mol ------- ans.**	1 1 1 1
3		**Any 3**	**12**
3	a	Basis: 100 kmol air	1

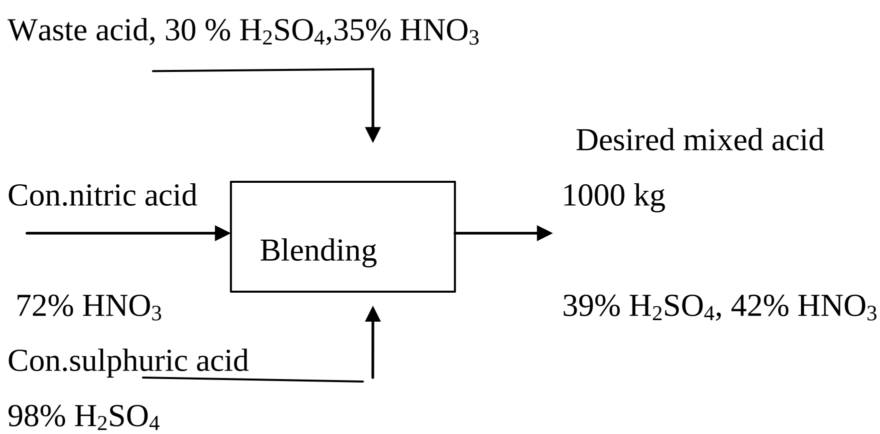
		Vol% = Mol% Avg. mol.wt of air = $M_1X_1 + M_2X_2$ = 32 * 0.21 + 28 * 0.79 = **28.84**	1 2
3	b	**Steps involved in solving material balance without chemical reactions:** 1.Assume suitable basis of calculation as given in problem. 2. Adopt weight units in case of problem of process without chemical reaction. 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:	4

	feed	product	Component removed
Unchanging component			
Outgoing component			

3	c	**Basis :** 100 kmol/hr acetaldehyde charged to reactor **Reaction :** $CH_3CHO + ½ O_2$ --------→ CH_3COOH	 1

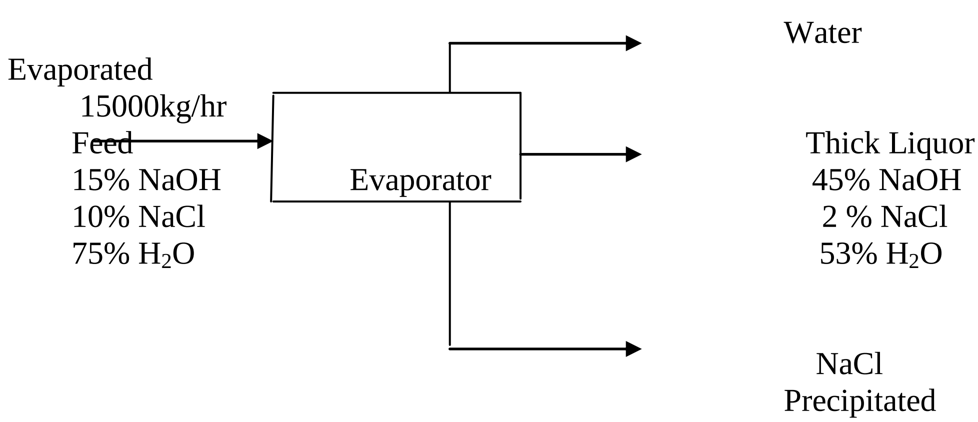
		Let X be the kmol of product obtained per hour Acetic acid formed = 0.5926 X kmol/hr Acetaldehyde unreacted = 0.1481 X kmol hr From reaction , 1 kmol CH_3CHO ≡ 1 kmol CH_3COOH Acetaldehyde reacted to produce acetic acid = 0.5926 X x (1/1) = 0.5926 X kmol/hr **Material balance of CH_3CHO** CH_3CHO fed 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
3	d	**Basis:** 1 mol of Na_2CO_3 $C_2H_5OH(g)$ + ----------→ CH_3CHO (g) + H_2(g) ΔH^o_R = Standard heat of reaction = [Σ ΔH^o_c] reactant - [Σ ΔH^o_c] product = [1 x (-1410.09)]– [1 x (-1192.65) + 1 x (-285.83)]	1 1

		= -1410.09 + 1478.48 = **68.39** KJ	2
4		**Any 3**	**12**
4	a	Force = 20 kgf Diameter of piston (d)= 5 cm Area = $\pi d^2/4$ $= \pi\ 5^2/4\ = 19.625 cm^2$ Pressure = F/area = 20/ 19.625= 1.019 kgf/cm^2 = 1.019* 9.808*10^4/1000 = **99.95 kPa**	 1 1 1 1
4	b	**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 (a) Average molecular weight of the Gaseous mixture Mavg = Σ MiXi $= M_{HCl}.X_{HCl} + M_{N2}.X_{N2} + M_{O2}.X_{O2}$ = 36.5 x 0.391 +28 x 0.481 + 32 x 0.127 ∴ Mavg = **31.80**	1 1

		(b)Volume occupied by this mixture T =303 K P= 405.3 kPa PV = nRT $\therefore V = \frac{nRT}{P}$ $= \frac{0.7 \text{ x } 8.3145 \text{ x } 303}{405.3}$ **= 4.35 m^3**	 1 1
4	c	**SOLUTION :** **BASIS :** 1000 kg of desired mixed acid.  **Block diagram for fortifying waste acid with concentrated acids**	1

		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)	
		Material Balance of H_2SO_4 :	
		$0.3\ x + 0.98\ y = 0.39 \times 1000$….(ii)	1
		$0.3\ x + 0.98\ y = 390$	
		$Y = (390 – 0.3\ x) / 0.98$	
		$\therefore\ Y = 397.96 – 0.306\ x$….(iii)	
		Material Balance of HNO_3 :	
		$0.35\ x + 0.72\ z = 0.42 \times 1000$	
		$0.35\ x + 0.72\ z = 420$…..(iv)	
		$z = (420 – 0.35\ x)/ 0.72$	
		$\therefore\ z = 583.3 – 0.486\ x$…..(v)	1
		Put values of y and z from equations (iii) and (v) in eqn (i) and solve for x.	
		$\therefore\ x + (397.96 – 0.306\ x) + (583.3 – 0.486\ x) = 1000$	
		$\therefore\ x = 90.1$ kg	
		We have , $y = 397.96 – 0.306\ x$	
		$= 397.96 – 0.30 \times 90.1$	
		$\therefore\ y = 370.4$ kg	
		We have , $z = 583.3 – 0.486\ x$	
		$= 583.3 – 0.486 \times 90.1$	
		$\therefore\ z = 539.5$ kg	
		Amount of waste acid required = 90.1 kg	
		Amount of concentrated sulphuric acid required = 370.4 kg	1
		Amount of concentrated nitric acid require = 539.5 kg ….Ans	

4	d	**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% $\text{Mole \% of A} = \frac{\text{Kmol A in product stream}}{\text{Total kmol of product stream}} * 100$ $2 = \frac{60 - X}{100 - X} * 100$ X = 59.184 kmol = amount of A reacted	 1 1 1

		Kmol A reacted Conversion of A = ------------------------------------ * 100 Total kmol of A feed 59.184 Conversion of A = --------- * 100 = **98.64 % ------ Ans** 60	 1
4	e	**Classification of fuels:** 1. Solid fuel- example: coke, wood, bagasse, charcoal 2. Liquid fuel – example: kerosene, petrol, diesel, methanol 3. Gaseous fuel – example: Acetylene, LPG, biogas,acetylene	4
5		**Any 2**	**12**
5	a	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 Vapour pressure = Partial pressure/ mol fr = 698/0.423 = **1650 mm Hg**	 2 2 2
5	b		1

		Basis : 15000 kg/hr of weak solution fed to the evaporator. Let X,Y,Z be the kg/hr of water evaporated thick liquor & Nacl precipitated respectively. Overall Material Balance : ΣInput stream =Σ Output stream 15000 = X + Y + Z Material balance of NaOH NaOH in feed = NaOH in thick liquor 0.15 x 15000 = 0.45 x Y $\therefore Y = 5000$ kg/hr Material balance of NaCl NaCl in feed = NaCl in thick liquor + NaCl precipitated 0.10 x 15000 = 0.02 x Y + Z $\therefore 1500 = 100 + Z$ $\therefore Z = 1400\frac{kg}{hr}$ We know X + Y + Z = 15000 $\therefore X = 8600\ kg/hr$ $\therefore Water\ evaporated = \mathbf{8600\frac{kg}{hr}}$ Thick liquor obtained = **5000 kg/hr** NaCl crystal precipitated =**1400 kg/hr**	1 1 1 1 1
5	c	Basis 100 mol of ethylene Reaction I $C_2H_4 + \frac{1}{2}O_2 \longrightarrow C_2H_4O$ Reaction II $C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$ From reaction I 1Kmol of C_2H_4O formed≡ 1Kmol C_2H_4 reacted	1

		$\therefore$ C_2H_4O reacted to from 80 kmol C_2H_4O $= \frac{1}{1} \times 80$ = 80Kmol From reaction II 2kmol of CO_2 formed≡ 1Kmol C_2H_4 reacted $\therefore C_2H_4$ reacted to form 10 kmol CO_2 $= \frac{1}{2} \times 10$ = 5Kmol $\therefore C_2H_4$ totally reacted = 80 + 5= 85 $\therefore$% conversion of $C_2H_4 = \frac{85}{100} \times 100$ = **85%** % yield of $C_2H_4O = \frac{80}{85} \times 100$ = **94.12%**	1 1 1 1 1
6		**Any 2**	**12**
6	a	**Basis :** 100 kg of product gases leaving the oxidizer Reaction : $4HCl + O_2 \rightarrow 2Cl_2 + 2 H_2O$ Product contains 13.2 kg HCl,6.3 kg O_2 ,42.9 kg N_2, 30 kg Cl_2 and 7.6 kg H_2O Quantity of HCl unreacted = 13.2 kg We have from reaction : 1 kmol HCl ≡ 2 kmol of Cl_2 146 kgl HCl ≡ 142 kg of Cl_2 Quantity of HCl reacted to produce 30 kg of Cl_2 = (146/.142) x 30 = 30.85 kg **Material balance of HCl**	1

HCl feed = HCl reacted + HCl unreacted = 30.85 + 13.2 = 44.05 Kg

Moles of HCl feed = (44.05/36.5) = 1.2068 kmol

We have from reaction : 1 kmol HCl ≡ 1 kmol of O_2 1

146 kgl HCl ≡ 32 kg of O_2

Quantity of O_2 reacted = (32/ 146) x 30.85 = 6.76 kg

Material balance of O_2

O_2 feed = O_2 reacted + O_2 unreacted = 6.76 + 6.3 = 13.06 kg

N_2 charged = N_2 in product gas = 42.9 kg 1

Air charged = (O_2 + N_2) in air charged = 13.06 + 42.9 = 55.96 kg

Moles of air charged = (55.96/28.84) =1.94 kmol

Theoretical O_2 required for 1.2068 kmol HCl = (1/4) x1.2068

= 0.3017 kmol

Theoretical air required = 0.3017 x (100/21) = 1.44 kmol

% excess air = (Air supplied – Air theoretically required)/ Air theoretically required x 100 1

= (1.94-1.44)/1.44 x 100 = 34.72 1

Composition of Gases Entering the reactor:

Component	Quantity in Kg	Weight %
HCl	**44.05**	**44.05**
O_2	**13.05**	**13.05**

		N_2 | **42.90** | **42.90** **Total** | **100.00** | **100.00**	1
6	b	**Basis :** 100 Kg of coke Amount of carbon in coke = 0.9 * 100 = 90 Kg Amount of C = 90/12 = 7.5 katom **Reaction :** $C + O_2$ ------> CO_2 From reaction , 1 katom C = 1 kmol O_2 12 Kg C = 32 Kg O_2 90 Kg C = (32/12)* 90 Kg O_2 O_2 theoretically required = (32/12)* 90 =240 Kg O_2 theoretically required = 240/32 = 7.5 kmol Air theoretically required = 7.5 * (100/21) =35.71 kmol % excess of air = 50% Air actually supplied = Air theoretically required (1+ % excess / 100) Air actually supplied = 35.71 * (1+ 50 / 100) **Air actually supplied = 53.57 kmol ------------- ans.**	1 1 1 1 1 1
6	c	**Basis:** 100 Kmol/min of CO_2 Q= Heat added $= n \int^{T_2} Cp\, dT$	1

		$= n \int_{T_1}^{T_2} [\, 21.3655 + 64.2841 \times 10^{-3}\, T - 41.0506 \times 10^{-6}\, T^2 + 9.7999 \times 10^{-9} T^3 \,]\, dT$	1
		$= n\, [21.3655\, (T_2 - T_1) + 64.2841 \times 10^{-3}/2\, (T_2^2 - T_1^2)$	
		$- 41.0506 \times 10^{-6}/3\, (T_2^3 - T_1^3) + 9.7999 \times 10^{-9}/4\, (T_2^4 - T_1^4)\,]$	1
		Where n= 100 kmol/min , T_2 = 383 K, T_1=298 K	
		$= 100\, [21.3655\, (383 - 298) + 64.2841 \times 10^{-3}/2\, (383^2 - 298^2) - 41.0506 \times 10^{-6}/3\, (383^3 - 298^3) + 9.7999 \times 10^{-9}/4\, (383^4 - 298^4)\,]$	1
		= 330335.5 KJ/min	2
		= 5505.6 KJ/s	
		Q = 5505.6 KW --------------- Ans.	