WINTER-18 EXAMINATION

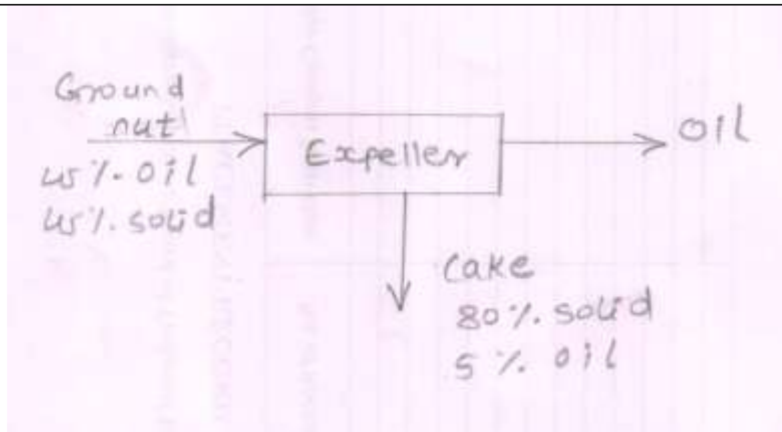
Model Answer

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	Sub q.no.	Answer	marks
	1	**Any 5**	**10**
1	a	**Units of temperature:** Degree Celsius(^{0}C) Degree Fahrenheit(^{0}F) Kelvin(K)	2
1	b	**Vander Waal's equation of state:** $(P+a/V^2)(V-b)= nRT$ Where a & b are constants. $a= 27 R^2 T_c^2 / 64 P_c$ $b = RT_c / 8 P_c$ Tc & Pc = Critical Temperature and Pressure	2
1	c	**Steady state operation**: Operations in which there is no buildup of mass and energy within the system as well as there is no variation or change in operating conditions of the system with time. **Unsteady state operation:** Operations in which buildup of mass and energy within the system as well as variation or change in operating conditions of the system with time.	1 1
1	d	**Stoichiometric coefficient** FeS_2 = 4 O_2 = 11 Fe_2O_3 = 2 SO_2 = 8	½ mark each
1	e	**Net Calorific value(NCV):** It is the calorific value of the fuel when the	1

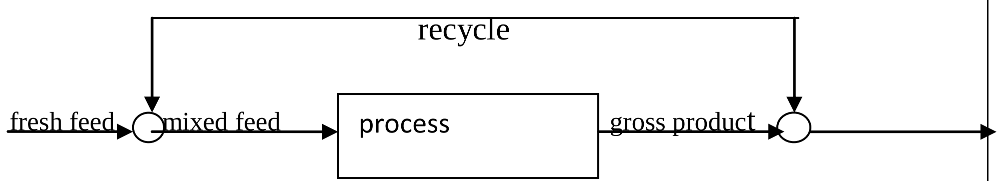
		water in the combustion products is present in vapour form **Gross Calorific value(GCV)**: It is the calorific value of the fuel when the water in the combustion products is present in liquid form	1
1	f	**Different forms of energy:** 1. Energy related to the system: kinetic energy, potential energy, internal energy, pressure energy, surface energy 2. Energy associated with the product: heat , work	1 1
1	g	**3 atm** = 3* 101.325 = 303.975 kPa = 3* 760 = 2280 mm Hg	1 1
2		**Any 3**	**12**
2	a	**SI units of:** 1. Energy : Joule(J) 2. Power : Watt(W) 3. Heat : Joule(J) 4. Work : Joule(J)	1 mark each
2	b	Basis:Gas in a closed vessel at 299 K $P_1V_1/T_1 = P_2V_2/T_2$ P_1=121.59 kPa g = 121.59 + 101.325 = 222.915 kPa absolute $V_1 = V_2$ T_1 =299 K P_2=? T_2 = 1273 K 222.915/299 = P_2/ 1273 P_2 = **949.07 kPa**	1 1 1 1
2	c	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 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
2	d	Basis 100 mol of ethylene Reaction I $C_2H_4 + \frac{1}{2}O_2 \longrightarrow C_2H_4O$ Reaction II $C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$	1

		From reaction I 1Kmol of C_2H_4O formed≡ 1Kmol C_2H_4 reacted $\therefore$ 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
3		**Any 3**	**12**
3	a	**Basis:** 100 kmol of flue gas. It contains 13.4 kmol CO_2,80.5 kmol N_2 and 6.1 kmol O_2 N_2 in supplied air = N_2 in flue gas = 80.5 kmol Air contains 79% N_2 by volume. Amount of air supplied = 80.5/ 0.79 = 101.9 kmol Amount of O_2 in supplied air = 0.21X101.9=21.4 kmol Amount of O_2 in flue gas = 6.1 kmol Amount of O_2 consumed in combustion of fuel = 21.4 - 6.1 = 15.3 kmol	1 1 1

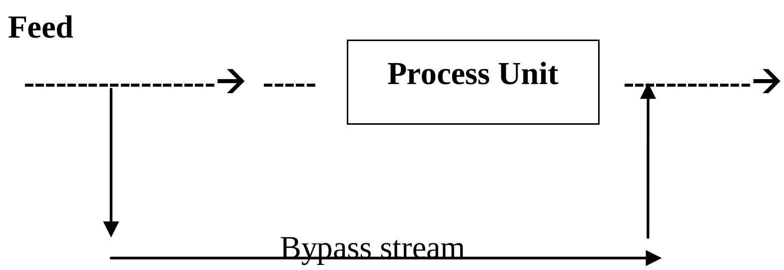
		% excess air = % excess O_2 Present excess air supplied = (21.4 – 15.3)/ 15.3 X 100 **= 39.9 % ------ Ans.**	1
3	b	**Basis:** 100 Kmol/min of CO_2 Q= Heat added $= n \int_{T_1}^{T_2} Cp\, dT$ $= n \int_{T_1}^{T_2} [\, 21.3655 + 64.2841 \times 10^{-3} T - 41.0506 \times 10^{-6} T^2 + 9.7999 \times 10^{-9} T^3 \,] dT$ $= n\ [21.3655 (T_2 - T_1) + 64.2841 \times 10^{-3}/2 (T^2_2 - T^2_1)$ $- 41.0506 \times 10^{-6}/3 (T^3_2 - T^3_1) + 9.7999 \times 10^{-9}/4 (T^4_2 - T^4_1)\ ]$ 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.**	1 1 1 1
3	c	**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	2

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 combined with the output stream.



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- Bypassing is practiced industrially whenever accurate control of the composition or concentration of the process exit stream is expected.
- The composition and properties of the product may be varied by varying the fraction of the feed that is bypassed.

Example: A juice concentration process in which the dehydration process runs most efficiently by removing more water than is desired. A portion of

		the feed may be directed around the dehydrator in a bypass loop, to be mixed with unprocessed feed. **Or** any other example	
3	d	Basis: 100 kmol gas sample Avg. mol.wt of air = $M_1X_1 + M_2X_2$ = 32 * 0.21 + 28 * 0.79 = **28.84** Density = P* Mav / RT = 1519.875 * 28.84/ 8.314 * 503 = **10.48 kg/m^3**	 1 1 1 1
4		**Any 3**	**12**
4	a	**Basis:** 1 mol of Na_2CO_3 $Na_2CO_3(s) + Fe_2O_3(s) \text{ ----------}\rightarrow Na_2O\,Fe_2O_3(s) + CO_2(g)$ ΔH^o_R = Standard heat of reaction = [Σ ΔH^o_c] reactant - [Σ ΔH^o_c] product = [1 x (-1130.68) + 1x (-817.3)] – [1 x (-1412.2) + 1 x (-393.51)] = -1947.98 + 1805.71 = **- 142.27** KJ	 1 1 1 1
4	b	**Basis:** 100 kmoles of producer gas $CO + ½ O_2 \text{ --}\rightarrow CO_2$ O_2 Theoretical = 27/2 =13.5 kmoles O2 required =13.5-1 = 12.5 kmoles % excess O_2 = (O_2 fed - O_2 theoretical) x 100 / O_2 theoretical 20 = (O_2 fed- 12.5) x100 / 12.5 O_2 fed = 15 kmoles	 1

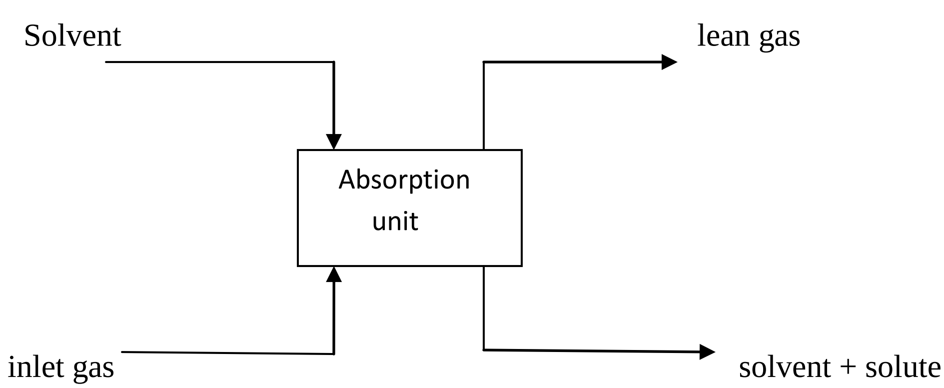
		N_2 fed = 56.43 kmoles CO reacted =0.98 x 27 = 26.46 kmoles CO unreacted = 27-26.46 = 0.54 kmoles CO_2 formed = 26.46 kmoles Total CO_2 = 26.46 + 6 = 32.46 kmoles Total N_2 = 56.43+66 = 122.43 kmloes O_2 reacted = 13.23 kmoles O_2 unreacted = 15-13.23 = 1.77 kmoles Composition by volume of flue gas;	1 1

component	kmoles	Mol%
CO_2	32.46	20.65
CO	0.54	0.344
O_2	1.77	1.126
N_2	122.43	77.88

(Marks: 1)

4	c	**Gas Absorption**: It is a unit operation in which a gas component from its mixture with other component gases is removed with the help of a suitable solvent in which the solute gas is absorbed.	1

Block diagram:



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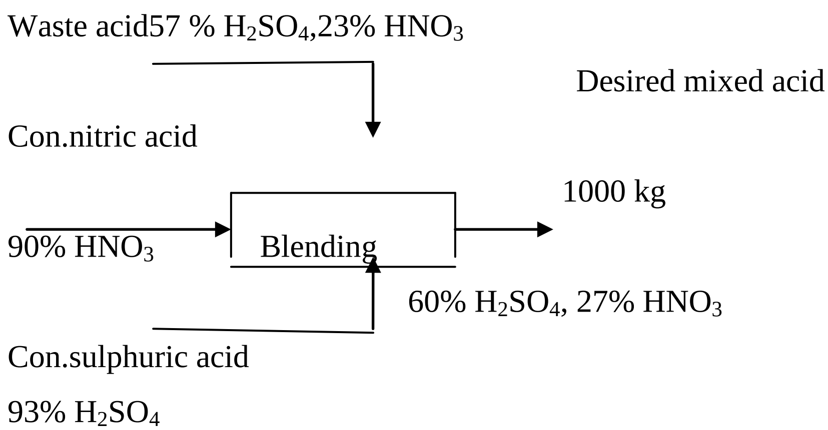
Material balance:

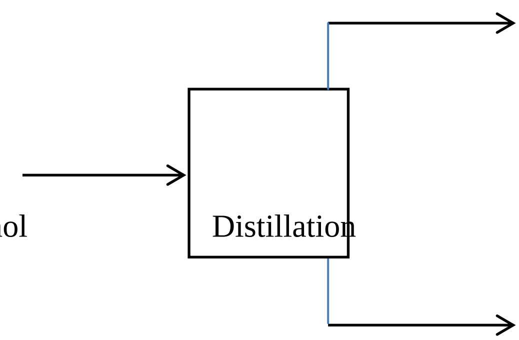
1. For inert gas

		Inert gas in gas entering tower = Inert gas in gas leaving tower 2. For solute gas Solute gas in inlet gas – solute gas in lean gas = solute gas absorbed	1
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% Mole % of A = $\frac{\text{Kmol A in product stream}}{\text{Total kmol of product stream}} * 100$	1 1

		$$2 = \frac{60 - X}{100 - X} * 100$$	1
		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
4	e	Heat required (sensible heat) Q= mCp (T_2-T_1)	1
		m = 100 kg	
		Cp = 4.187 kJ/kg K	
		T1 = 40+273 =313 K	1
		T2 = 90 +273 = 363 K	
		Q = 100 kg x 4.187 kJ/kgK x (363-313) K	1
		= **20935 kJ**	1
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	2
		Applying Raoults law to butane	
		Partial pr = Mol fr * vapour pr	1
		Vapour pressure = Partial pressure/ mol fr	
		= 698/0.423	1

		= **1650 mm Hg**	2
5	b	**SOLUTION :** **BASIS :** 1000 kg of desired mixed acid.  **Block diagram for fortifying waste acid with concentrated acids** 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 :** 0.57 x + 0.93 y = 0.6 x 1000….(ii) 0.57 x + 0.93 y = 600 **Material Balance of HNO_3 :** 0.23 x + 0.90 z = 0.27 x 1000 0.23 x + 0.9 z = 270…..(iii)	1 1 1 1

		Solving the above three equations, we get X= 416.89 Y= 389.65 Z= 193.46 **Amount of waste acid required = 416.89kg** **Amount of concentrated sulphuric acid required = 389.65kg** **Amount of concentrated nitric acid required = 193.46kg ….Ans**	 1 1
5	c	Basis: 100 kmol cyclohexane $C_6H_6 + 3 H_2 \rightarrow C_6H_{12}$ Cyclohexane produced = 100 kmol Benzene reacted to produce 100 kmole cyclohexane = 100 kmoles Yield of cyclohexane = 90% 90 = (C_6H_6 reacted to produce C_6H_{12} / kmoles of C_6H_6 totally reacted)x 100 C_6H_6 totally reacted = 111.11 kmoles Conversion of C_6H_6 =50% 50 = (C_6H_6 reacted / C_6H_6 fed)x 100 C_6H_6 fed = **222.22 kmoles** Theoretical H_2 required = 666.67 kmoles Excess H_2 = 30% 30 =(H_2 fed-H_2 theoretical/ H_2 theoretical) x 100 H_2 fed **= 866.67 kmoles**	 1 1 1 1 1 1
6		**Any 2**	**12**
6	a	**Basis :** 15000 Kg/hr of weak solution fed to evaporator Let X,Y and Z be the kg/h of water evaporated ,thick liquor and NaCl precipitated as crystal **Overall Material Balance :**	 1

		15000 = X + Y --------(1)	1
		Material balance of NaOH	
		NaOH in feed solution = NaOH in thick Liquor	1
		0.15 x 15000 = 045 Y -------------(2)	
		Material balance of NaCl	
		Nacl in feed solution = NaCl in thick liquor + Nacl crystal obtained	1
		0.10 x 15000 = 0.02 x 5000 + Z	
		Z = 1400 kg /hr	
		Put X and Y in equation (1)	
		X + 5000 + 1400 = 15000	1
		X = 8600 kg/hr	
		Water evaporated = 8600 kg/hr	
		Thick liquor obtained = 5000 kg/hr	1
		NaCl precipitated as Crystal = 1400 kg/hr	
6	b	Basis : 1000 kmol Benzen- Toluene mixture	
		Top product X kmol	1
			
		Feed 100 kmol Distillation	
		Residue Y kmol	
		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** % recovery of benzene = $\frac{\text{benzene in distillate}}{\text{Benzene in feed}} * 100$ % recovery of benzene = $\frac{254.47}{280} * 100$ **% recovery of benzene = 90.88 %** -------- ans. (b)	1 1 1 1 1
6	c	**SOLUTION :** **BASIS :** 100 kmol of SO_2 and 100 kmoles of O_2 fed $SO_2 + ½ O_2 \longrightarrow SO_3$ O_2 supplied = 100 kmol Conversion of SO_2= 80% SO_2 reacted = 100 x 0.80 = 80 kmol	 1 1

O_2 reacted = 80 x 0.5

= 40 kmol 1

SO_3 formed = 80 kmol 1

Composition of gases leaving reactor :- 2

Product	**Quantity,Kmol**	**Mole %**
SO_2	100 – 80 = 20	12.5
O_2	100 – 40 = 60	37.5
SO_3	80	50
Total	160	