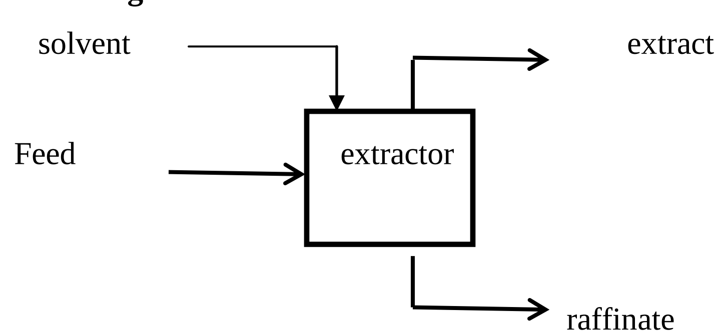
WINTER-17 EXAMINATION

Model Answer

Important Instructions to examiners:

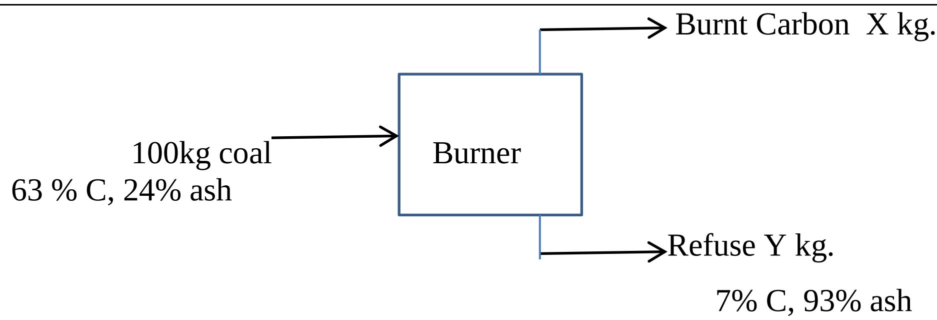
1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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	**Pure component volume:** Pure component volume of a component gas is the volume that would be occupied by that component gas if it alone was present in the same pressure and at the same temperature as the gas mixture.	2
1A-c	5 kg O_2 Molecular weight of O_2=32 Moles of O_2 = weight / molecular weight = 5 / 32 = 0.15625 kmoles = **156.25 gmoles**	2
1A-d	**Law of conservation of mass:** Material input = material output + accumulation	2
1A-e	**Block diagram for extraction** 	2
1A-f	**Selectivity:** Selectivity may be defined as the ratio of the moles of the desired	2

	product to undesired or by product produced in a side reaction. -Selectivity are applicable to a set of chemical reaction-complex reaction	
1-B	**Any 2**	12
1-B a	Basis: 100 kmol gas sample Avg. mol.wt of air **=** $M_1X_1+ M_2X_2+ M_3X_3$ = 16 * 0.66 + 44 * 0.3 + 17 *0.04 = **24.44** Density = P* Mav / RT = 304 * 24.44/ 8.314 * 303 = **2.95 Kg/m^3**	1 1 1 1 2
1-B b	Basis: 100 kg mixture Weight of H_2 = 11.1 kg = 5.55kmoles Weight of O_2 = 88.9 kg = 2.78kmoles Average molecular weight = 2*0.67 + 32*0.33 = **11.9** Partial pressure of H_2 = Total pressure * mol.fraction = 100Kpa * 0.67 = **67 Kpa** Partial pressure of O_2 = Total pressure * mol.fraction = 100Kpa * 0.33 = **33 Kpa**	 1 1 1 1 1 1
1-B c	Basis: CO-N_2 mixture Weight of CO =N_2 = 100 kg. Kg. moles of CO = 100/28 = 3.57 Kg. moles of N_2 = 100/28 =3.57 Mole fraction of N_2 = 0.5 Total pressure = 405.3 KPa	1 1 1

	Partial pressure of CO = total pressure * mole fraction of CO = 405.3 * 0.5 = **202.65 KPa**	1 2
2	**Any 4**	16
2-a	**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
2-b	Basis : 100 kg. of coal.	

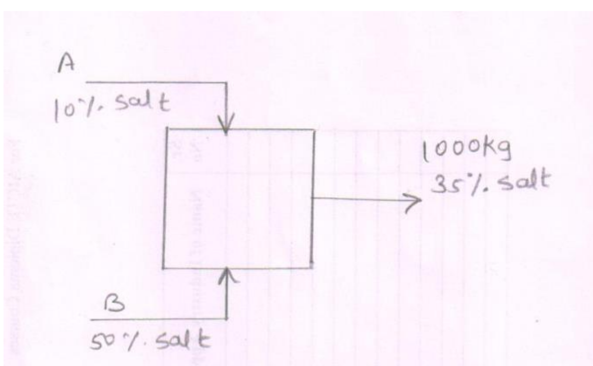
	feed	product	Component removed
Unchanging component			
Outgoing component			

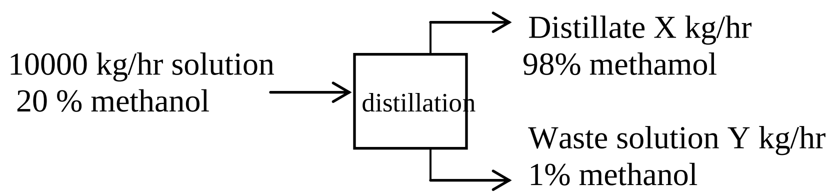
	 	1
	Individual balance for ash. 24 = 0.93 Y Y = 25.80 kg. Balance for carbon	 1
	63 = X + 0.07 * 25.80	1
	X = 61.194 kg. Unburnt carbon = 0.07 * 25.8 = 1.806 kg.	 1
	% of original carbon unburnt =(1.806/63) * 100 = **2.867%**	
2-c	**1)Stoichiometric Equation :** The stoichiometric equation of a chemical reaction is the statement indicating relative moles of reactant and products that take part in the reaction .	 1
	For example, the stoichiometric equation $CO + H_2 \text{------}\rightarrow CH_3OH$	 1
	Indicates that one molecule of CO react with two molecules of hydrogen to produce one molecule of methanol	
	2) Stoichiometric Coefficient : It is the number that precedes the formula of each component involved in a chemical reaction.	 1
	For example, the stoichiometric equation $CO + H_2 \text{------}\rightarrow CH_3OH$	 1

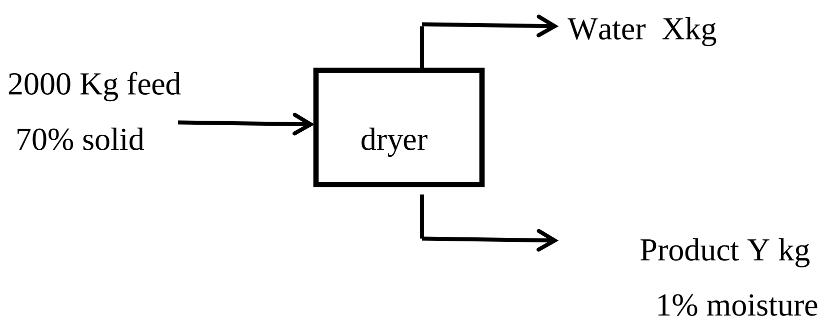
	In above example Stoichiometric Coefficient of CO is one, Stoichiometric Coefficient of H_2 is Two and Stoichiometric Coefficient of methanol is one **(Students may write other suitable example)**	
2-d	$SO_2 + ½ O_2 \longrightarrow SO_3$ SO_2 fed = 100 kg. moles SO_3 formed = 80 kg. moles 1 kg. mole 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-e	**Differentiate Conversion and Yield :** (see table below)	1 mark each

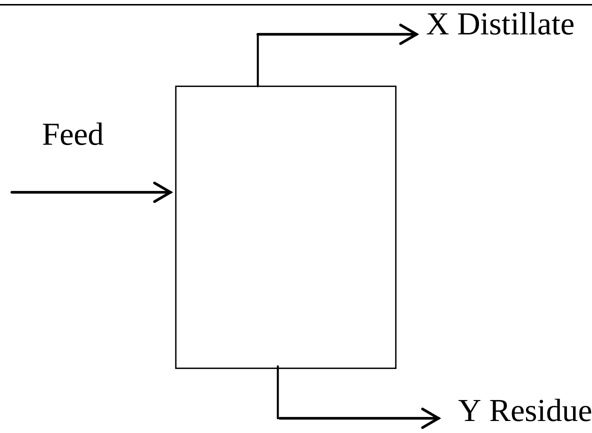
Conversion	Yield
1.Conversion is the ratio of the amount of reactant reacted to the initial amount of the reactant	**1. Yield** of a desired product is the ratio of the quantity of the desired product actually obtained to its quantity maximally obtainable.
2. Conversion gives us idea regarding how efficient 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. | **4. Yield** is applicable to Complex reaction	
2-f	C^0_{pm} = 29.3955KJ / (K mol. K) Moles of air (n) = 3 T = 473K T_0 = 298 Heat added Q = n* C^0_{pm} (T – T_0) = 3*29.3955(473-298) = **15432.64 KJ**	 1 1 2
3	Any 2	16
3-a	**Solution:** **Basis:** 3000 kg of monochloroacetic acid production per batch. Mol. Wt. of $CH_2ClCOOH$ = 94.5 Moles of $CH_2ClCOOH$ 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 = $\frac{CH_3COOH \text{ reacted} \times 100}{\% \text{ conversion}}$	 1 1 1 1

	$= \frac{31.75}{0.95}$ = 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, Theoretical requirement of Cl_2 For 33.42 kmol $CH_3COOH = \frac{1}{1} \times 33.42 = 33.42$ kmol Given : 15% excess Cl_2 is used. Therefore, Cl_2 fed/supplied $= 33.42 \times (1 + \frac{15}{100}) = 38.43$ kmol $\therefore$ Amount of Cl_2 required per batch = 38.43 × 71 = **2728.5 kg** Amount of CH_3COOH required per batch = 33.42 × 60 = **2005.2 kg**	1 1 1 1
3-b	BASIS:1000 kg of final solution.  Let kg of A=x Let kg of B=y Therefore overall balance X+y=1000 ……………………(1) Salt balance 0.1x+0.5y=1000*0.35	1 1 1

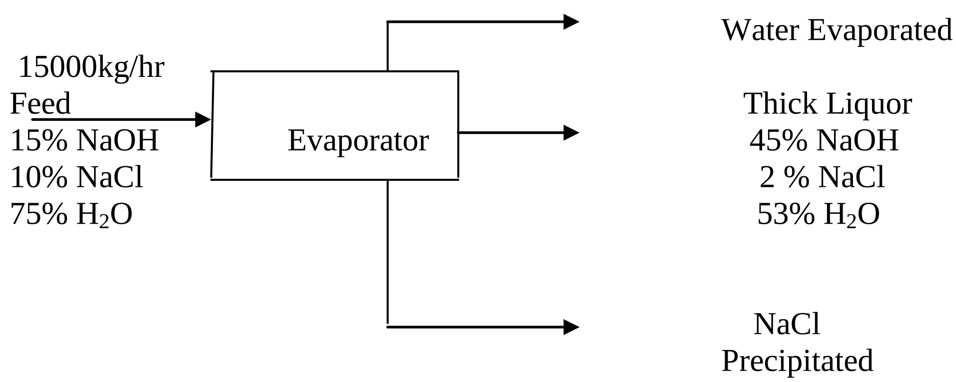
	0.1x+0.5y=350 ……………………….(2)	1
	Multiplying equation (1) by 0.1	
	0.1x+0.1y=100 ……………………….(3)	
	From eqution (2) and (3)	
	4y=250	
	Therefore y=250/4	
	=625kg	3
	X=375kg	
	Wt of 10% solution=375 kg	1
	Wt of 50% solution=625kg	
3-c	Basis: 10000 kg/hr of feed	1
		2
	Overall balance is	
	10000 =X+ Y……………(1)	1
	Individual balance for CH_3OH is	
	0.2*10000 = 0.98X+0.01*Y…………..(2)	1
	Solving the equations	
	X**= 1958.76 Kg/hr**	
	Y= 8041.24 kg/hr	3
	Mass flow rate of distillate = **1958.76 Kg/hr**	
	Mass flow rate of bottom product = **8041.24 kg/hr**	
4	**Any 2**	**16**

4-a	Basis: 1 mol liquid C_5H_{12} $\Delta H^0_R = \Sigma\ \Delta H^0_{f(pr)} - \Sigma\ \Delta H^0_{f(react)}$ = [(-822.7)+(-296.81*4)]– (-178.02*2) = **-1653.9KJ**	1 2 2 3
4-b	Basis: 2000 kg wet solid  Overall balance is 2000 = X+ Y Balance for solid 0.70 * 2000 = 0.99 * Y Y = 1414.14 kg X = 585.86 Water removed = **585.86 kg** Product obtained = **1414.14 kg**	1 2 1 1 2 1
4-c		

		1
	Basis 5000kg of feed.	1
	xF = 50%	
	xD = 95%	
	xW= 8%	
	Weight of Benzene in feed = 5000×0.5	
	= 2500kg	
	Overall balance	1
	x + y = 5000	
	Material balance of benzene	
	$0.95x + 0.08y = 5000 \times .5$	1
	$.95x + 0.08y = 2500$	
	Solving for x & y	
	(x) Flow rate of top product= **2413.79 kg**	2
	(y) Flow rate of bottom product **= 2586.21 kg**	
	% Recovery of Benzene	1
	$= \frac{2293.10}{2500} \times 100$	1

	= **91.72%**	
5	Any 2	16

5-a



1

Basis : 15000 kg/hr of weak solution fed to the evaporator. 1

Let X,Y,Z be the kg/hr of water evaporated thick liquor & Nacl precipitated respectively.

Overall Material Balance :

$$\Sigma \text{Input stream} = \Sigma \text{ Output stream}$$

$$15000 = X + Y + Z$$ 1

Material balance of NaOH

NaOH in feed = NaOH in thick liquor 1

$$0.15 \times 15000 = 0.45 \times Y$$ 1

$$\therefore Y = 5000 \text{ kg/hr}$$

Material balance of NaCl

NaCl in feed = NaCl in thick liquor + NaCl precipitated 1

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

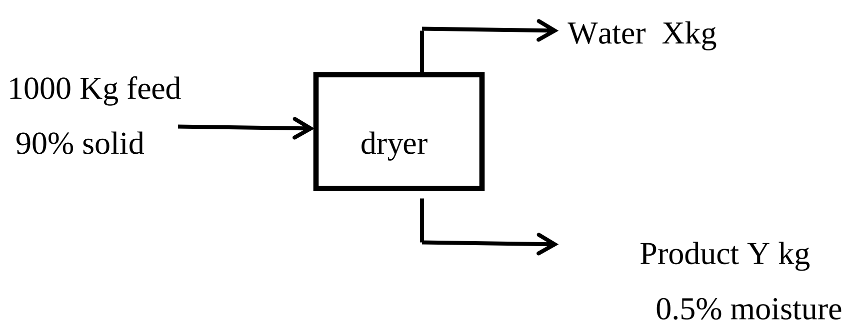
$$\therefore 1500 = 100 + Z$$

$$\therefore Z = 1400 \frac{kg}{hr}$$ 1

	We know X + Y + Z = 15000 $\therefore X = 8600\ kg/hr$ $\therefore Water\ evaporated = \mathbf{8600}\,\frac{\mathbf{kg}}{\mathbf{hr}}$ Thick liquor obtained = 50**00 kg/hr** NaCl crystal precipitated =1400 **kg/hr**	1
5-b	**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 % excess air = % excess O_2 Present excess air supplied = (21.4 – 15.3)/ 15.3 X 100 **= 39.9 % ------ Ans.**	1 1 1 1 1 1 1 1
5-c	**Basis :** 1 Kmol of methane gas Q = Heat added $Q = n\int_{T_1}^{T_2} C^o p\ dT$ $Q = n\int_{T_1}^{T_2} [\,19.2494 + 52.1135 * 10^{-3}\,T + 11.973 * 10^{-6}\,T^2 - 11.3173 * 10^{-9}\,T^3]\ dT$ $52.1135 * 10^{-3}$	1 1 2

	$= n [19.2494 (T_2 - T_1) + \frac{52.1135 \times 10^{-3}}{2} (T_2^2 - T_1^2)$ $+ \frac{11.973 \times 10^{-6}}{3} (T_2^3 - T_1^3) - \frac{11.3173 \times 10^{-9}}{4} (T_2^4 - T_1^4)]$ Where , n= 1Kmol, T_2 = 523 K , T_1 = 303 K $Q = 1 [19.2494 (523 - 303) + \frac{52.1135 \times 10^{-3}}{2} (523^2 - 303^2)$ $+ \frac{11.973 \times 10^{-6}}{3} (523^3 - 303^3) - \frac{11.3173 \times 10^{-9}}{4} (523^4 - 303^4)]$ Q = 4234.9 + 4735 + 459.9 - 187.8 Q = **9242 KJ**	2 2
6	**Any 4**	16
6-a	**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) ------> CO_2 (g) ----- Δ H Path 2 : (i) C (s) + ½ O_2 (g) ------> CO (g) ----- Δ H1 (ii)2CO (g) +½ O_2 (g) ------> CO_2 (g) ----- Δ H2 -- (i) + (ii) C (s) + O_2 (g) ------> CO_2 (g) Thus Δ H = Δ H1 + Δ H2	2 2
6-b	**Adiabatic Reaction:** It is the reaction which proceeds without loss or gain of heat, When the	

	adiabatic reaction is exothermic, the temperature of the product stream rise and when the adiabatic reaction is endothermic, the temperatures of the product stream decreases **Adiabatic reaction temperature:** Temperature of product under adiabatic condition is called adiabatic reaction temperature.	2 2
6-c	**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 = 10% Air actually supplied = Air theoretically required $\left(1+\frac{\%\ excess}{100}\right)$ Air actually supplied = 35.71 * $\left(1+\frac{10}{100}\right)$ **Air actually supplied = 39.281 kmol ------------- ans.**	1 1 1 1
6-d	$N_2 + 3H_2$ ---→ $2NH_3$ Assume nitrogen is the limiting component.	

	For 4 moles of nitrogen fed, theoretical requirement of hydrogen is 12 kmoles. But hydrogen fed is only 10 kmoles. Therefore nitrogen is not the limitinhg component. Therefore Hydogen is the limiting component and **Nitrogen is the excess component.** N_2 fed = 4 kmoles Theoretical requirement nitrogen corresponding to N_2 fed 4 kmoles = 3.33 % excess N_2 = (kmoles N_2 fed- kmoles N_2 theoretical/ kmoles N_2 theoretical)* 100 = (4-3.33/3.33)*100 = **20.12%**	1 1 1 1
6-e	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**	1 1 1

	Product obtained = **904.52 kg** **% of original water removed = (**Water removed/original water 0*100 = (95.48/100)*100 =**95.48%**	1
6-f	Basis – 50Kmol SO_2 150 Kmol air Reaction $SO_2 + \frac{1}{2}O_2 = SO_3$ Air used = 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 read = $\frac{100}{21} \times 25$ = 119.05 Kmol $\therefore$% excess air used = $\frac{150-119.05}{119.05}$	1 1 1 1

	= 26%	