Q.No	Answer	Remark
1.a	Henry's law: It states thatpartial pressure of a solute gas is proportional to mol fraction of that component in liquid phase. $P_A = H x_A$ P_A – partial pressure of A x_A – mol fraction of A in liquid phase H – Henrys law constant	2 marks
1.b	PV= nRT is ideal gas law. The constant R in ideal gas law is called universal gas constant.	1 mark
	It is used to find out the conditions like pressure, temperature, volume and mole of an ideal gas.	1 mark
1.c	Vanderwaals equation is used to find out the conditions like pressure, temperature, volume and mole of non ideal or real gas.	2 mark
1.d	Charles law: It states that for a given mass of an ideal gas, the ratio of volume to absolute temperature is constant at a given pressure.	1 mark
	V/T = constant OR for a given mass of an ideal gas, the volume is directly proportional to absolute temperature at a given pressure.	1 mark
1.e	Material balance is Material input= material output + accumulation	1 mark
	Steps for material balance: 1. Mark incoming and outgoing streams 2. Take overall balance 3. Take component balance 4. Solve the equations to get unknowns	Any 2 steps ½ mark each
1.f	Recycle: To increase the conversion of reactant, unreacted reactants are separated from the products and send back to the reactor for further reaction. This is called recycling.	2 marks
1.g	% conversion= <u>moles of reactant reacted</u> * 100 　　　　　　Moles of reactant fed	1 mark
	% yield = <u>moles of reactant reacted to form desired product</u> *100 　　　　Total moles of reactant reacted	1 mark
1.h	HCV(higher calorific value) of fuel is equal to the lower calorific value of a fuel to which latent heat of water vapour is added.	1 mark
	LCV(lower calorific value) of fuel is the calorific value which is determined by considering that the water is present in vapour form.	1 mark
1.i	Specific heat: It defined as the amount of heat required to increase the temperature of one gram of substance by one degree..	1 mark
	Latent heat: It is defined as the heat required to change the phase of a substance at constant temperature.	1 mark
1.j	Unit of heat in MKS system is Kilocalorie and kilojoules(KJ)	2 marks
1.k	<u>Energy balance</u>: The total amount of energy entering any system must be exactly equal to the energy leaving plus any accumulation within system.	1 mark
	Energy balance is important because it gives an idea about the amount of heat involved in the system or operation.	1 mark
1.l	Sensible heat: It defined as the amount of heat required to change the	1 mark

	temperature of a substance. Adiabatic reaction: It is the reaction which proceeds without loss or gain of heat.	1 mark
2.a	Ideal gas law: PV=nRT	1 mark
	For an ideal gas mol%=Vol%	1 mark

component	Mole %	Mole fraction(x_i)	Mol. Wt(M_i)	M_i*x_i
CH_4	70	0.7	16	11.2
C_2H_6	2.2	0.022	30	0.66
N_2	8	0.08	28	2.24

Average mol. Wt =14.1

Density= PM_{avg}/RT

= 101.325*14.1/8.314*288

= 0.6 Kg/m^3

2.b(i) Volume % = Mol%

component	Mole %	Mole fraction(x_i)	Mol. Wt(M_i)	M_i*x_i
H_2	15.6	0.156	2	0.312
O_2	84.4	0.844	32	27.008

M_{avg} = 27.32

2.b(ii)

P= 0.968 atm

T= 298 K

Mol wt =28

R= 0.08206 lit atm/ gmol K

Density= P*Mol.wt/ RT

= 0.968* 28/0.08206*298

= 1.108 gm/lit

2.c(i)

PV=nRT

V= 3.1 lit = $3.1*10^{-3} m^3$

P= 300 KP

R= 8.314 KPa m^3/kgmol

T= 293 K

n=PV/RT

= $3.82*10^{-4}$ kgmoles

2.c(ii)

PV=nRT

n=PV/RT

= 12*0.315/ 0.08206* 298

= 0.155 gmol

Weight of oxygen = 0.155*32

= 4.95 gms

Marks (right column, top to bottom): 4 marks, 2 marks, 1 mark, 3 marks, 2 marks, 2 marks, 1 mark, 1 mark, 1 mark, 1 mark

2.c(iii)	PV=nRT n= PV/RT $= 100 * 10^{-3} / 0.08206 * 423$ $= 2.84 * 10^{-5}$ kg mol $= 2.84 * 10^{-2}$ gmol Mol. Wt = Wt/ Moles $\qquad$ = 88.24	1 mark 1 mark
2.c(iv)	PV=nRT n=PV/RT $= 1 * 0.098 / 0.08206 * 300$ $= 3.98 * 10^{-3}$ gmol Molar mass= wt/ moles $\qquad = 0.081/3.98 * 10^{-3}$ $\qquad = 20.35$	1 mark 1 mark

Q.3 a)   04 marks – each table (1 mark for each point)

	Mixing	Blending
1.	Mixing is generally employed for mixing of two solids.	Blending is used for mixing of two liquids.
2.	Composition throughout may not be same	Composition at any point will be same.
3.	Mixing of Concentrate	Blending of Perfume
4.	Sigma Mixer, etc. equipment's is used.	Blender, etc. equipment's is used.

|	Absorption	Extraction
1.	Gas-Liquid Contacting	Liquid – Liquid Contacting
2.	Solubility of gas in solvent is driving force.	Solubility of one component in solvent is driving force.
3.	Mass Transfer Operation	Mass Transfer Operation
4.	Absorption Column, etc. equipment's is used.	Mixer Settler, etc. equipment's is used.

b) 1. By passing operation is recycling of unreacted feed material to process again.

2. It converts unconverted material.

3. Accurate control in component on concentration is expected.

4. Properties & Composition of products may be varied by varying fraction of

feed that is bypassed.

Bypass Stream

Feed   Product

Process Unit
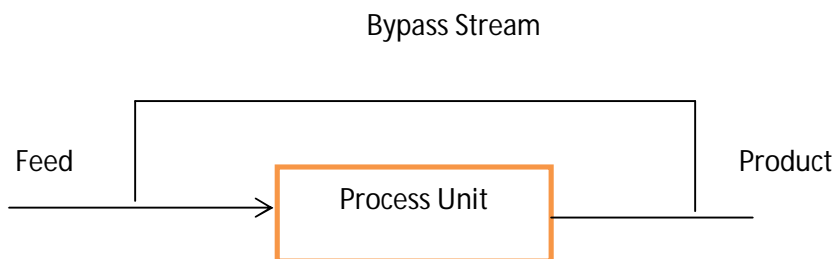
4 marks ----- diagram ,,, 4 marks --- explaination

c). Material Balance without Chemical Reaction:

- Assume the basis for solving the problem.
- Decide the changing or unchanging component.
- Write overall Balance for the process.
- Write material balance for tie component.
- Solve the two equations to get value of output & Accumulated or deleted Component.

Water Evaporated

Feed

Evaporator

Concentrated Solution
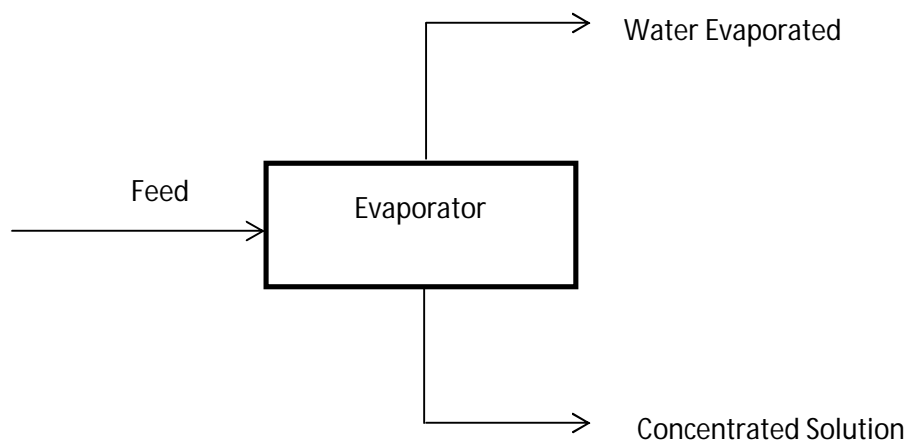
Overall Balance:
    Feed = Water Evaporated + Concentrated Solution
    $F = V + C$ -------------------------------------- 1
    Material Balance of Solids:
    $F * X_F = C * X_C$ --------------------------------------- 2
        Solve the two equation to get value of V & C.

4 marks ---- steps to solve ,,, 4 marks --- for examples

Q. IV. a. Basis: 100 Kmoles of gas mixture   ------- 1 mark

Vol % = Mol %

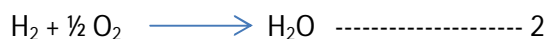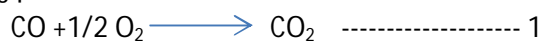Kmoles of CO_2 =   5.0

Kmoles of CO =   20.5

Kmoles of H_2 =   16.0

Kmoles of CH_4 =   0.5

Kmoles of N_2 =   58.0

_____

100.0

Reaction taking place   ------ 2 marks

$$CO + 1/2\ O_2 \longrightarrow CO_2 \text{ ------------------- 1}$$
$$H_2 + \frac{1}{2}\ O_2 \longrightarrow H_2O \text{ -------------------- 2}$$
$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O \text{ -------- 3}$$

1. Kmoles of O_2 required in 1st reaction   -------- 2 marks

= 0.5* 20.5

= 10.25

2. Kmoles of O_2 required for 2nd reaction

= 0.5 *16

= 8

3. Kmoles of O_2 required for 3rd reaction

= 2* 0.5

= 1

Total Kmoles of O_2 required

= 10.25+ 8 + 1

= 19.25 Kmoles

Total O_2 supplied = 19.25 * 1.1

= 21.175 Kmoles

N_2 associated with O_2 ------ 2 marks

= 79/21 * 21. 175

= 79.65 Kmoles

CO_2 produced in reaction 1 &3

= 20.5 + 0.5

= 21 Kmoles

H2O produced in reaction 2 & 3

= 16 + 1.0

= 17 kmol

Unreacted O2 = 21.175 – 19.25

= 1.925   %

Product gas CO_2 = 21 +5 = 26 14.24   -------------- 01 mark

H_2O   **= 179.3111**

	Unreacted O_2	= 1.925	1.054
1.	N_2 = 58 + 79.65	= 137.65	75.393

$$182.575 \qquad 99.99$$

b. Basis: 100 kmol of product   ------ 1 mark

Gas	kmol
CH_3OH	8.6
CH_2O	3.1
HCOOH	0.6
H_2O	3.7
O_2	16.0
N_2	68

$$100.0$$

Chemical reaction

$$CH_3\,OH + \tfrac{1}{2}\,O_2 \longrightarrow CH_2O + H_2O \qquad \text{------ 2 marks}$$
$$CH_2O + \tfrac{1}{2}\,O_2 \longrightarrow HCOOH$$

1. Kmol of CH_2O formed = 3.1

Kmol of methanol reacted = 1* 3.1   -----1 mark

           = 3.1 Kmol of CH3OH

Total Kmoles of CH3OH fed

      = 3.1 +8 *.6

      = 11.7 Kmols

2. % conversion of methanol = 3.1 /11.7 * 100   ----- 1 mark

                       = 26.49

       1 kmol of HCOOH = 1 Kmol reacted

       0.6 of CH2O   = 0.6 kmol of CH_3OH reacted

       % M

       = 0.6/ 11.7 * 100

       = 5.12

3. Mole ratio of Air to Methanol   ------ 2 mark

       1st reaction = 3.1/2 = 1.55

       2nd reaction = 0.6/2 0.3/1.85 kmol O2

       79 kmol of N_2 = 100 Kmol of Air

       68 Kmol of N_2 = 68/79 * 100

       = 86.075 Kmol

       86.075/11.7 = 7.356 kmol of Air/ Kmol of Methane

4.   1.85/1.85+16 *100   86.075* 0.21   ---- 1 mark

        = 1.85/17.85 * 100   = 18.07

= 10.36 %   1.85/18. 07 * 100

$$= 10.23$$

$$18.07 - 1.85 = 16.22$$

C.   02 marks for each point

1. Stoichiometric equation of a chemical reaction is the statement indicating relative moles of
    reactants and products that take part in the reaction. eg

    $$CO + 2H_2 \longrightarrow CH_3OH$$

2. Stoichiometric ratio : it is the ratio of stoichiometric coefficient of two molecular species or
    Components in the balanced reaction

    $$CO_2/ H_2 = \frac{1}{2}$$

3. Excess component : is one which is in excess of theoretical or stoichiometric requirement.
    Excess component is always found in product side equation.

4. Selectivity:

$$A \longrightarrow C$$
$$A \longrightarrow D$$

Where C is desired component
    and D is undesired component

$$Selectivity = \frac{Moles\ of\ C\ formed}{Moles\ of\ D\ formed}$$

Q.No	Answer	Remark
5. **(a)**	Basis: 1 mol Carbon disulphide(CS_2)	01 mark
	Reaction	
	$$C(s) + 2S(s) \longrightarrow CS_2(l)$$	02 marks
	$\Delta H^o_f (CS_2)$ = Std. Heat of formation of CS_2	
	$= [\Delta H^o_C \text{ Reactant} - \Delta H^o_C \text{ Product}]$	01 mark
	$= [(1*393.3)+(2*-293.72)]-[1*-1108.76]$	
	$= [-194.14]-[-1108.76]$	03 marks
	$= 914.62$ KJ/mol	01 mark
(b)	Basis: 1 mol methane and 3 mol oxygen feed	01 mark
	Reaction	
	$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$	01 mark
	From reaction	
	1mol of CH_4 = 2 mol O_2	01 mark
	0.5 mol of CH_4 = 1 mol O_2	
	For 1 mole CH_4 = 2mole O_2 required but feed O_2 is 3 mole, hence	
	Limiting component is Methane(CH_4)	02 marks
	Excess component is Oxygen (O_2)	
	Theoretical O_2 requried =2 mol, Actually Supplied O_2=3 mol	
	% Excess of Oxygen = $\dfrac{3 - 2}{2}$ * 100 = 50%	01 mark
	% conversion of methane = $\dfrac{0.5}{1}$*100 = 50%	01 mark
	% conversion of oxygen = $\dfrac{1}{3}$*100 = 33.33%	01 mark

(c)	Basis : 50Kmol/hr methane and 2500 Kmol/hr air feed Reaction: $CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$	01mark
	O_2 in supplied air=0.21*2500=525 kmol/hr	01 mark
	N_2 in supplied air=2500-525= 1975 kmol/hr	
	Theoretical requirement of O_2 = (2/1)*50=100 kmol/hr	
	% excess air = % excess O_2	
	$= \dfrac{525\text{-}100}{100}*100$ $= 425\%$	01 mark
	Combustion is complete, $\quad$ O_2 reacted=100 kmol/hr Material Balance of O_2 $\quad$ O_2 in supplied air = O_2 reacted- O_2un reacted	
	O_2un reacted = 525-100=425 kmol/hr	01mark
	1 kmol CH_4= 1 kmol CO_2	
	CO_2 produced =(1/1)*50=50kmol/hr	01 mark
	1 kmol CH_4= 2 kmol H_2O	
	H_2O produced =(2/1)*50=100 kmol/hr	01 mark
	Material Balance of N_2 $\quad$ N_2 in supplied air = N_2 in Combustion gas=1975 kmol/hr	01mark
	Composition of Combustion Gases:	

Component	Quantity , Kmol	Mole %
CO_2	50	1.96
H_2O	100	3.92
O_2	425	16.66
N_2	1975	77.45
Total	2550	100

01mark

06.		
(a)	Basis : 01 mol Ethyl acetate($C_4H_8O_2$)	01 mark
	1) $C(s)+O_2(g)$-----→ $CO_2(g)$ $\quad$ $\Delta H1$= -393.51 KJ/mol	
	2) $H_2(g)+0.5\ O_2(g)$-----→ $H_2O(l)$ $\quad$ $\Delta H2$= -285.83 KJ/mol	03 marks
	3) $C_4H_8O_2(l)+5O2(g)$-----→ $4CO_2(g) + 4\ H_2O(l)$ $\quad$ $\Delta H^o c$= -2230.91 KJ/mol	
	4) $4C(s)+4H_2(g)+O_2(g)$-----→ $C_4H_8O_2(l)$ $\quad$ ΔH_f = ?	
	$\quad$ ΔH_f = Heat of formation of Ethyl acetate(C4H8O2)	
	Reaction 4 = 4*Reaction 1+ 4* Reaction 2- Reaction 3	01 mark
	$\quad$ = $[(4*\Delta H1) +(4*\Delta H2)] - \Delta Hc$ $\quad$ =[(4*-393.51)+(4*-285.83)]-(-2230.91) $\quad$ =[-1547.04+(-1143.32)]-(-2230.91) $\quad$ =-2717.36+ 2230.91	02 mark
	$\quad$ = -486.45 KJ/mol	01mark
(b)	Basis : 4000 Kg/hr of Chlorinated diphenly Let Q be the heat to be added to the fluid in heater	01 mark
	$Q = m\int_{T1}^{T2} C.dT$	01 mark
	$Q = m\int_{T1}^{T2} (0.7511+1.465*10^{-3}\ T)\ dT$	01 mark
	$Q = m[07511(T2-T1)+ \dfrac{1.465*10^{-3}}{2}\ (T2^2-T1^2)]$ Where m=4000Kg/hr T1= 313 K T2=533 K	02 marks
	$Q = 4000[07511(533-313)+ \dfrac{1.465*10^{-3}}{2}\ (533^2-313^2)]$	02 mark
	$\quad$ = 4000(180.26+152.24) $\quad$ = 133*10^4 KJ/hr $\quad$ = 369.44 KJ/S or KW	01 mark

(c)	**i) Crystallization:** It is the formation of solid particle within a homogeneneous liquid phase. Crystallization gives almost pure product . Crystallization of the dissolved solids from a solution is based on difference in solubility of solute at different temperature	02 marks
	ii) Filtration: This operation is carried in industry for the separation of solids from a suspension in liquid by porous medium. Wet solid is the product of this operation. Various equipments used are centrifuge, Drum –Filter Plate-Frame filer etc.	02 marks
	iii)Percentage excess air: It is the amount by which the air feed to combustion chamber exceeds the theoretical air $$\text{Percentage excess air}=\frac{(\text{Moles air Supply- Moles air theoretical Required})}{(\text{Moles air theoretical required})} *100$$ The quantity of air supply theoretical air can be used either in weight or molar units in formula	02 marks

	iV)Orsat Analysis and Wet analysis:
	    Orsat analysis is used to analyze flue gas .It gives the analysis of Carbon Monoxide(CO),Carbon di oxide(CO_2),Oxygen (O2) and Nitrogen(N_2) by Volume
	    Wet analysis is used to analyze flue gas. It gives the analysis of Carbon Monoxide(CO),Carbon di oxide(CO_2),Oxygen (O2) and Nitrogen(N_2)and Water by Volume
		02 marks (01 mark each)