Why beating is required in the manufacture of pulp?

2 Mention the steps involved in the manufacture of sugar

3 What are the uses of bagasse?

4 What are the industrial applications of starch?

5 Name four industrial fermentation products

6 What is meant by hydrogenation in oil and fat industry?

7 What are soaps and detergents?

8 What are the uses of fatty acids?

9 What are the byproducts from natural gasoline?

10 What are heavy distillates?

11 What are the characteristics of petroleum refining?

12 What is meant by catalytic reforming?

13 How are plastics classified?

14 What are the ways in which polymerization takes place?

15 Name three synthetic fibers

16 Give one example of polyester

17 Name three synthetic rubbers

18 Name two tanning processes in leather industry

19 Vegetable tanning is used for what type of materials?

20 Classify the dyes

Part B (5 x 12 = 60 Marks)

(a) Describe the manufacture of sulphate pulp including black liquor recovery

Or

(b) Discuss the various gasification processes of coal with neat diagram

(a) Describe the manufacture of industrial alcohol from molasses with the help of a flow chart

Or

(b) What is soap? How is soap manufactured?

(a) Discuss the products obtained from the refining of petroleum and indicate their commercial uses

Or

(b) What is sweetening? List the different sweetening treatments used in petroleum processing. Discuss any one method in detail

(a) What are plastics? What are the basic differences between thermoplastic, thermosetting and elastomer resins. Give examples

Or

(b) (i) Discuss about different types of resins

(ii) Describe the manufacture of phenol-formaldehyde resin with a neat flow diagram (5 + 7)

(a) Describe the viscose process for the manufacture of Rayon fiber indicating in detail the steps involved

Or

(b) (i) Compare natural and synthetic rubbers

(ii) How is natural rubber prepared? What are its important properties (6 + 6)

Process Calculations - Problems

1 1000 litres of a mixture of H_2, N_2 and CO_2 at 150oC was found to have the following ratio for the partial pressures of the gases: $P_{H_2} : P_{N_2} : P_{CO_2}$ is 1:4:3. If the total pressure is 2 atm absolute, calculate
a)Mole fraction of each of these gases.

b)Weight percent of each of these gases.

c)Average molecular weight and

d) Weight of CO_2 in kg.

2 A dryer with a capacity of 800 kg/day operates on a material which is 90% H_2O and 10% solid. The product which contains 20% H_2O is dried in another dryer until the water content is 2%. Calculate the % of the original water which is removed in each dryer and the weight of product from each dryer.

3 In order to obtain barium in a form that may be put into solution, the natural barytes, containing only pure barium sulfate and infusible matter, is fused with an excess of pure, anhydrous soda ash. Upon analysis of the fusion mass it is found to contain 11.3% barium sulfate, 27.7% sodium sulfate and 20.35% sodium carbonate. iThe remainder is barium carbonate and infusible matter. Calculate

iiThe % conversion of barium sulfate to barium carbonate

iiiThe composition of original barytes and The % excess of sodium carbonate used above the theoretical amount required for reaction with all the barium sulfate.

4 Air at a temperature of 20oC and 750 mm Hg has a relative humidity of 80%. Calculate
i the molal humidity of the air

ii the molal humidity of this air if its temperature is reduced to 10oC and pressure increased to 2000 mm Hg condensing out some of the water, and

iii weight of water condensed from 1000 litres of the original wet air in cooling and compressing to the conditions of part (ii).

Vapor pressure of water at 20oC = 17.5 mm Hg
Vapor pressure of water at 10oC = 9.2 mm Hg.

5 A fuel oil containing 88.2% Carbon and 11.8% Hydrogen (by weight) is burnt with 20% excess air. 95% of the carbon is burnt to carbon dioxide and the rest to carbon monoxide. All the hydrogen is converted to water. Determine the Orsat analysis of the flue gas.

6 A furnace uses a natural gas which consists of entirely hydrocarbons. The flue gas analysis is CO_2 : 9.5%, O_2 : 1.4%, CO : 1.9% and the rest to N_2. Calculate
i atomic ratio of hydrogen to carbon in the fuel
ii percentage excess air used
iii composition of the fuel gas in the form C_xH_y.

7 The gases from a sulfur have the following analysis: SO_2 : 9.86%, O_2 : 8.54%, N_2 : 81.6%. After passage of the gases through a catalytic converter, the analysis (SO_3

free basis) is SO_2 : 0.6%, O_2 : 4.5%, N_2 : 94.9%. What % of the SO_2 entering the converter has been oxidized to SO_3?

8 The analysis of gas entering the converter in Contact H_2SO_4 plant is SO_2 : 4%, O_2 : 13% and N_2 : 83% (on volume basis). The gas leaving the converter contains 0.45% SO_2 on SO_3 free basis (by volume). Calculate the % of SO_2 entering the converter getting converted to SO_3.

9 17.2 grams of N_2O_4 gas, when heated to 100oC at 720 mm Hg undergoes 90% dissociation according to the equation N_2O_4 à $2NO_2$. Calculate the volume occupied at 100oC and 720 mm Hg assuming ideal gas law.

10 A gaseous mixture contains 1 kg of helium, 5 kg of ammonia and 10 kg of nitrogen at 344.1 K and 2 atm absolute pressure. Calculate:
i the composition in mole percent

ii the partial pressure of each component

iiithe molal density of the mixture, and

iv the average molecular weight.

11 A solvent recovery system delivers gas saturated with benzene vapor which analyses on a benzene-free basis 15% CO_2, 4% O_2 and 81% N_2. This gas is at 21.1oC and 750 mm Hg pressure. It is compressed to 5 atmosphere and cooled to the same temperature after compression. How many kg of benzene are condensed by this process per 1000 m3 of the original mixture if the vapor pressure of at 21.1oC is 75 mm Hg?

12 A distillation column separates an ethyl alcohol feed into high purity alcohol and waste water. The feed has a composition of 20 mole percent of ethyl alcohol. The distillate contains 85 mole percent ethyl alcohol and the bottoms have a 3 mole percent alcohol concentration. If the feed is charged to the column at the rate of 45 kmol/hr, calculate

i the quantity of distillate and bottoms

ii what percentage of alcohol in the feed is recovered in the distillate?

13 In a causticization process, NaOH is produced by adding a solution containing 10% by weight of sodium carbonate in the stoichiometric proportions to an inlet slurry containing 25% by weight of calcium hydroxide. If the inlet slurry is charged at the rate of 100 kg/hr, what would be the composition of the final slurry if the reaction goes to 99% completion? What is the amount of sodium hydroxide produced?

14 Formaldehyde is manufactured by the catalytic oxidation of methanol using an excess of air according to the reaction I. A secondary oxidation II also occurs if the conditions are not properly controlled.
$CH_3OH + 0.5O_2$ à $HCHO + H_2O$ -- I

$HCHO + 0.5O_2$ à $HCOOH$ -- II

In a test run the product gases have the following composition by volume: CH_3OH = 8.6% ; HCHO = 3.1% ; HCOOH = 0.6% ; H_2O = 3.7% ; O_2 = 16.0% ; N_2 = 68%. Calculate the following:
Percentage conversion of methanol to formaldehyde

Percentage of methanol lost due to reaction II.

Molar ratio of air to methanol used.

15 Natural gas containing CH_4 = 83% and C_2H_6 = 17% was burnt with an excess of dry air. The Orsat analysis of the flue gas was CO_2 = 6.76% ; CO = 2.77% ; O_2 = 5.63% ; N_2 = 84.84%. Calculate the following:
percentage excess air supplied

percentage completion of oxidation of carbon

amount of fuel gas produced per 100 m3 of fuel at 500oC and 1 atmosphere pressure.

16 Carbon dioxide is produced by recovering CO_2 from flue gas. The flue gas is passed up through an absorber in contact with an aqueous solution of Na_2CO_3. The flue gas contains 20 percent (by volume) of CO_2. The effluent gas from the absorber contains 9 percent CO_2 (by volume). How many kg moles of flue gas are required to produce 1000 kg of CO_2 if 90 percent of the CO_2 absorbed is recovered as product?

17 8000 kg of an aqueous solution containing 25 percent (by weight) of anhydrous sodium sulfate are fed to a crystallizer. The solution is cooled and 15% of the initial water is lost by evaporation. $Na_2SO_4.10H_2O$ crystallizes out. If the mother liquor (solution after crystallization) contains 18.3% (by weight) of anhydrous Na_2SO_4, calculate the weight of mother liquor and crystals obtained.

18 Air at 1 atmosphere (absolute) and 40oC containing 0.053 kmol water/ kmol of dry air is to be conditioned to 30oC containing 0.018 kmol of water/ kmol of dry air by cooling part of the air to 25oC containing 0.012 kmol of water/ kmol of dry air and mixing it with the uncooled air. The resulting mixture is reheated to 30oC. For 1000 m3/min of wet air at 30oC and containing 0.018 kmol of water/ kmol of dry air, calculate:

volume of entering wet air, and

percentage of entering air which is bypassed.

19 In a process to manufacture HCl, common salt and sulfuric acid are heated together. The HCl gas produced is cooled and absorbed in water to produce 31.5% HCl (by weight). Some HCl is lost during absorption. To produce 1 ton of 31.5% HCl, 550 kg of common salt and 480 kg of 98% H_2SO_4 were taken. The reaction goes to completion. Calculate:
Which reactant is in excess?

What is the amount of HCl lost?

Calculate the composition and quantity of residue left behind when 50% of water is distilled off.

20 A liquid containing 47.5% acetic acid and 52.5% water is to be separated by solvent extraction using isopropanol. The solvent used is 1.3 kg per kg of feed. The final extract is found to contain 82% acid on solvent free basis. The residue has 14% acid on solvent free basis. Find the percentage extraction of acid from the feed.

21 When heated to 100oC and 720 mm Hg pressure, 17.2 gm of N_2O_4 gas occupy a volume of 11.45 litres. Assuming that ideal gas law applies calculate the % dissociation of N_2O_4 to NO_2.

22 Paper is passing continuously through a tunnel drier. The entering paper contains 10 % water (dry basis i.e., 10 kg water/100 kg dry paper) and the leaving paper contains 2% water (dry basis). How many kg of water is evaporated per hour if 1000 kg/hr of paper enters the drier?

23 Chlorobenzene is nitrated using mixed acid. A charge consisted of 100 kg of chlorobenzene, 106.5 kg of 65.5% nitric acid, and 93.6% sulfuric acid. After 2 hours of operation it was found that 2% of the feed chlorobenzene remained unreacted and the product distribution was 66% p-nitrochlorobenzene and 34% o-nitrochlorobenzene.

Calculate the analysis of charge

percentage conversion of chlorobenzene

the composition of the products.

24 In a vessel at 200 kN/m2 and 310 K, % relative humidity of water vapor in air is 25. The partial pressure of water vapor when air is saturated with vapor at 310 K is 6.3 kN/m2. Calculate:
humidity of air Percentage humidity

.

25 Carbon tetra chloride is to be removed from a polymer solution by bubbling dry air through it at 297 K. The resulting mixture has % relative humidity of 70. It is required to remove 90% of carbon tetra chloride present by cooling to 283 K, and compressing to a suitable pressure. What this pressure should be?
Data: Vapor pressure of CCl_4 at 297 K = 12.2 kN/m2 and at 283 K = 6 kN/m2

26 280 kg of nitrogen and 64.5 kg of hydrogen are brought together and allowed to react at 515oC and 300 atm pressure and from the experimental measurements it is found that there are 38 kmol of gases present at equilibrium.

How many kmol of N_2 and H_2 and ammonia are present at equilibrium?

Which is the limiting and which is the excess reactant?

How much excess hydrogen is there?

What is the amount of theoretically required hydrogen?

What is the percentage conversion of hydrogen to ammonia?

27 Methanol is produced by the reaction of carbon monoxide with hydrogen.
$CO + 2H_2$ à CH_3OH. -- I

The side reaction is

$CO + 3H_2$ à $CH_4 + H_2O$ -- II

At a pressure of 70.3 kgf/cm2 (absolute) and a temperature of 301.5oC, the conversion per pass is 12.5%, and of this amount 87.5% is assumed to react via equation I and 12.5% via equation II. The stream leaving the reactor passes through a condenser and a separator. Carbon monoxide and hydrogen, leaving this unit are recycled. The leaves as a gas and the liquid mixture of methanol and water passes to a distillation column for the concentration of methanol. Fresh feed gas contains 32 mole % CO and 68 mole % H_2 at 65.5oC and 70.3 kgf/cm2 (absolute). Recycle stream is also at 70.3 kgf/cm2 (absolute) and 301.5oC. Calculate:

Analysis, mole % and weight % of hot gaseous stream leaving the reactor.
Methanol content, weight % of liquid (Methanol + water) stream, leaving the condenser and separator.
Recycle ratio expressed as kg of CO and H_2 recycled per kg of fresh feed gas.

28 What will be the composition of the gases obtained by burning pure FeS_2 with 60% excess air? Assume that the reaction proceeds in the following manner:
$4FeS_2 + 11O_2$ à $2Fe_2O_3 + 8SO_2$.

29 Calculate the total pressure and the composition of vapors in contact with a solution at 100oC containing 35% benzene, 40% toluene and 25% xylene by weight.
Data: Vapor pressures at 100oC Benzene: 1340 mm Hg
Toluene: 560 mm Hg
Xylene: 210 mm Hg

30 Two engineers are calculating the average molecular weight of a gaseous mixture containing oxygen and other gases. One of them using the correct molecular weight of 32 determines the average molecular weight correctly as 39.2. The other using an incorrect value of 16 determines the average molecular weight as 32.8. This is the only error in the calculations. What is the amount of oxygen in the mixture expressed in mole % and weight %?

31 Pure carbon dioxide may be prepared by treating limestone with dilute sulfuric acid. The limestone contains $CaCO_3$ and $MgCO_3$ with a small quantity of inert matter. The acid used is 12% H_2SO_4. During the process the mass was warmed and CO_2 and water vapor were removed. The residue from the process has the following composition:
$CaSO_4$ 8.56%
$MgSO_4$ 5.23%
H_2SO_4 1.05%
Inerts 0.53%
CO_2 0.12%
Water 84.51%

Total 100.00%

Calculate the following:

The analysis of limestone used; and

The percentage of excess acid used.

32 Antimony (Sb) is produced by heating powdered Sb_2S_3 and Fe and removing molten Sb from the reaction vessel. If 1.8 kg of Sb_2S_3 and 1.3 kg of Fe are heated to give 0.9 kg of Sb, calculate
Limiting and excess reactants

Percentage excess reactant

Degree of completion

Percentage conversion.

33 Natural gas containing 80% CH_4, 15% C_2H_6 and 5% C_3H_8 is burnt with 50% excess air. Assuming that 90% of the hydrocarbons are converted to CO_2 and the rest to CO, determine
Fuel gas analysis
Orsat analysis

34 The gaseous reaction A à 2B + C takes place isothermally in a constant pressure reactor. Starting with a mixture of 75% A and 25% inerts (by volume), in a specified time the volume doubles. Calculate the conversion achieved.

35 In the Deacon process for manufacturing chlorine, hydrochloric acid gas is oxidized with air. The reaction taking place is
$4HCl + O_2 \rightarrow 2Cl_2 + 2H_2O$

If the air is used in excess of 30% of that theoretically required, and if the oxidation is 80% complete, calculate the composition by volume of dry gases leaving the reaction chamber.

36 In a particular crystallization process, 2500 kg of $Na_2SO_4.12H_2O$ crystals are obtained. The mother liquor leaving the process contains 20% Na_2SO_4 anhydrous by weight. If the feed solution contains 35% Na_2SO_4 and 25% of the original H_2O is lost by evaporation, determine:
weight of original solution and mother liquor
percentage recovery

37 Nitrogen from a cylinder is bubbled through acetone at 1.1 bar and 323 K at the rate of 2 x 10-4 m3/min. The nitrogen, saturated with acetone vapor leaves at 1.013 bar, 308 K at the rate of 3.83 x 10-4 m3/min. What is the vapor pressure of acetone at 308 K?

38 Limestone mixed with coke is being burnt in a kiln. An average analysis of the limestone is $CaCO_3$: 84.5%, $MgCO_3$: 11.5% and the rest inerts. The coke contains

76% carbon, 21% ash and 3% moisture. The calcination of $CaCO_3$ is only 95% complete and that of $MgCO_3$ is 90%. The carbon in the coke is completely burnt to CO_2. The kiln is fed with 1 kg of coke per 5 kg of limestone. Calculate weight percent CaO in the product leaving the kiln.

39 Pure propane (C_3H_8) is burnt in an excess of air to give the following analysis of combustion products in volume percent:
CO_2 = 5.0, CO = 3.5, H_2O = 11.4, O_2 = 7.0 and N_2 = 73.1
Calculate the percentage of excess air used.

40 A mixture of NH_3 and air at 720 mm Hg and 40o contains 6.3% NH_3 by volume. The gas is passed at the rate of 100 m3/hr through an absorption tower in which only NH_3 is removed. The gases leave the tower at 715 mm Hg and 30oC containing 0.09% NH_3 by volume. Using ideal gas law, calculate
Rate of flow of gas leaving the absorber.
Weight of NH_3 absorbed in kg/hr

41 The analysis of 15000 litre of gas mixture at standard conditios is as follows:
CO_2 = 9.5% ; SO_2 = 0.5% ; O_2 = 12.0% ; N_2 = 78.0%.
How much heat must be added to this gas to change its temperature from 25oC to 700oC?
Data: Specific heat values in kcal/(kmol.oK)

Gas	CO_2	SO_2	O_2	N_2
Cp at 25oC	8.884	9.54	7.017	6.961
Cp at 700oC	11.303	11.66	7.706	7.298

42 10 kmol of zinc are to be heated from 0oC to 1000oC. It melts at 419oC and boils at 907oC. Determine the heat required for the process.
Data:
Cpm of solid Zn = 0.105 kcal/kg oC
Cpm of molten Zn = 0.109 kcal/kg oC
Cpm of vapor Zn = 4.97 kcal/kmol
l vap = 26900 kcal/kmol

Use Trouton's rule to estimate the latent heat of melting.

43 An evaporator is fed with10000 kg/hr of a solution containing 1% solute by weight. It is to be concentrated to 1.5% solute by weight. The feed is at a temperature of 37oC. The water is evaporated by heating with steam available at a pressure of 1.34 atm absolute, corresponding to a temperature of 108.3oC. The operating pressure in the vapor space is 1 atm absolute. Boiling point elevation and other effects can be neglected. The condensate leaves at the condensing temperature. All the physical properties of the solution may be taken to be same as that of water. What is the quantity of steam required per hour? What is the quantity of steam required per hour?
Data:
Enthalpy of feed = 38.1 kcal/kg
Enthalpy of solution inside the evaporator (at 100oC) = 644 kcal/kg
Enthalpy of vapor at 100oC = 644 kcal/kg
Latent heat of vaporization of steam = 540 kcal/kg

44 Calculate the theoretical flame temperatre of a gaseous fuel containing 20% CO, and 80% N_2 when burnt with 100% excess air, both air and gas initially being at 25oC. Heat of combustion of carbon monoxide = 67636 kcal/kmol.
Data: Specific heats of products of combustion in kcal/(kmol.oK)
Carbon dioxide: $Cp = 6.339 + 10.14 \times 10^{-3}T$

Oxygen: Cp = 6.117 + 3.167 x 10-3T
Nitrogen: Cp = 6.457 + 1.389 x 10-3T
where T = temperature in Kelvin

45 100 kg/hr of an organic ester of formula C19H36O2 is being hydrogenated to C19H38O2 by a continuous process. The company purchases its hydrogen in cylinders of 10 m3 capacity initially at 70 bar and 303 K. If the company buys 50 days demand of H2 at a time, how many cylinders it should order? For H2, Tc = 33 K, Pc = 12.8 bar. Vanderwaals constants are given by a = (27R2Tc2/64Pc) and b = (RTc/8Pc) where R = 0.08 lit.atm/gmol.oK. Use Vanderwaals equation for solving the problem.

46 A wet organic pigment 35% by weight of CCl4 is to be dried to 5%. The drier is to operate adiabatically with fresh plus recycle air entering the drier with 0.43 kg of CCl4/kg of dry air. The air leaves the drier with 0.945 kg of CCl4/kg of dry air. The capacity of the drier is 200 kg of bone dry solid/hr. Calculate the ratio of the recycled air to fresh air.

47 In a textile mill 20% by weight solution of caustic soda required for mercerization is prepared in the following way: First caustic soda is dissolved in correct quantity of water to produce 50% by weight of solution, cooled to remove all heat of dissolution and then diluted to 20% concentration with required quantity of water in the dilution tank. Evaluate the weight ratio of water added to dissolution tank and water flowing through the bypass line to dilution tank.

48 The reaction A à 2B + C takes place in a catalytic reactor (diagram is given below). The reactor effluent is sent to a separator. The overall conversion of A is 95%. The product stream from the separator consists of B, C and 0.5% of A entering the separator, while the recycle stream consists of the remainder of the unreacted A and 1% of B entering the separator. Calculate the single pass conversion of A in the reactor molar ratio of recycle to feed.

49 Air at 30oC and 150 kPa in a closed container is compressed and cooled. It is found that the first droplet of water condenses at 200 kPa and 15oC. Calculate the percent relative humidity of the original air. The vapor pressures of water at 15oC and 30oC are 1.7051 kPa and 4.246 kPa respectively.

50 Methanol vapor can be converted into formaldehyde by the following reaction scheme:
CH3OH + 0.5 O2 à HCHO + H2O

CH3OH à HCHO + H2

The fresh feed to the process was 0.5 kmol / hr of O2 and an excess methanol. All of the O2 reacts in the reactor. Formaldehyde and water are removed from the product stream first, after which H2 is removed from the recycled methanol. The recycle flow rate of methanol was 1 kmol/hr. The ratio of methanol reacting by decomposition to that by oxidation was 3. Draw the flow diagram and then calculate the per pass conversion of methanol in the reactor and the fresh feed rate of methanol.

51 A stock containing 1.526 kg moisture per kg dry solid is dried to 0.099 kg moisture per kg dry solid by countercurrent air flow. Fresh air entering contains 0.0152 kg water per kg dry sir and the exit air has 0.0526 kg water per kg dry air. What fraction of air is recycled if 52.5 kg of dry air flows per 1 kg of dry solid inside the drier?
An evaporator is fed continuously with 25 kg/hr of a solution which contains 10% NaCl,

10% NaOH and 80% H_2O. During evaporation, H_2O is removed from the solution and NaCl precipitates as crystals which is settled and removed. The concentrated liquor leaving the evaporator contains 50% NaOH, 2% NaCl and 48% H_2O. Calculate
(i)Weight of salt precipitated per hour.
(ii) Weight of concentrated liquor leaving per hour.