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2200+ Solved Questions

for

GATE, PSUs & State Engineering Examinations

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Preface

This Chemical Engineering practice book containing nearly 2200+ solved questions focuses in-depth understanding of subjects which has been segregated topicwise to disseminate all kind of exposure to students in terms of quick learning and deep apt. The topicwise segregation has been done to align with contemporary competitive examination pattern. Attempt has been made to bring out all kind of probable competitive questions for the aspirants preparing for GATE, PSUs and State Engg. Exams. The content of this book ensures threshold level of learning and wide range of practice questions which is very much essential to boost the exam time confidence level and ultimately to succeed in all prestigious engineers' examinations. It has been ensured from MADE EASY team to have broad coverage of subjects at chapter level.

While preparing this book utmost care has been taken to cover all the chapters and variety of concepts which may be asked in the exams. The solutions and answers provided are upto the closest possible accuracy. The full efforts have been made by MADE EASY Team to provide error free solutions and explanations.

I have true desire to serve student community by way of providing good sources of study and quality guidance. I hope, this book will be proved an important tool to succeed in competitive examinations. Any suggestions from the readers for the improvement of this book are most welcome.

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CMD, MADE EASY Group

CONTENTS

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UNIT 1

Process Calculations

1. Composition and Degree of Freedom

Q.1 Select the correct statement(s) from the following:
(a) A tie component is that component whose quantity changes during a particular reaction or operation.
(b) A tie component is that component whose quantity doesn't change during a particular reaction or operation.
(c) Conversion is to do with reactants and yield with products.
(d) Conversion is to do with products and yield with reactants.

Q.2 With rise in pressure, the solubility of gases in solvent at a fixed temperature
(a) Increases
(b) Decreases
(c) Remains unchanged
(d) Decreases linearly

Q.3 Which of the following statement is/are true about degree of freedom analysis?
(a) If the degrees of freedom are negative that means the unit operation is under specified.
(b) If the degree of freedom are positive that means the unit operation is over specified.
(c) If the degree of freedom is zero then the unit operation is well-defined.
(d) For a well-defined operations, it is theoretically possible to solve for the unknowns with a finite set of solutions.

Q.4 Increasing the temperature of an aqueous solution will cause decrease in its
(a) Molality (b) Mole fraction
(c) Weight fraction (d) Molarity

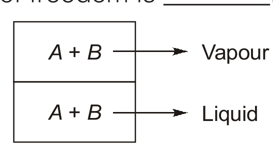
Q.5 Which of the following statements is/are true about Gibbs phase rule?
(a) The Gibbs phase rule identifies the degree of freedom of a multi phase system that is in thermodynamic equilibrium.
(b) It relates the number of extensive independent thermodynamics properties for each phase and the number of phases for a system.
(c) It relates the number of intensive independent thermodynamic properties for each phase and the number of phases for a system.
(d) For a system that does not experience a chemical reaction, the Gibbs phase rule reads as follows:
$\pi + f = N + 2$, where
π = Phases
N = Components
f = Number of intensive independent properties

Q.6 The degree of freedom for the case of pure liquid water and solid ice in equilibrium is ________.

Q.7 The degree of freedom for the case of pure liquid water, solid ice and water vapour in equilibrium is ________.

Q.8 The degree of freedom for the case of solid ice in equilibrium with a liquid mixture of ethanol + water is ________.

Q.9 Consider the following diagram for the mixture of *A* and *B* which are in equilibrium, the required degree of freedom is ________.



Q.10 Which of the following statement is correct about the degree of freedom?
(a) Degree of freedom is equal to the number of independent variables present in the system minus the number of equations of constraint between the variables.
(b) Degree of freedom is equal to the number of dependent variables present in the system minus the number of equations of constraint between the variables.

(c) Degree of freedom is equal to the number of independent variables present in the system plus the number of equations of constraint between the variables.
(d) Degree of freedom is equal to the number of dependent variables present in the system minus the number of equations of constraint between the variables.

Q.11 A mixture of nitrogen and carbon dioxide at 298 K and 101.325 kPa has an average molecular weight of 31. What is the partial pressure of nitrogen?
(a) 100 kPa (b) 82.33 kPa
(c) 78.57 kPa (d) 17.67 kPa

2. Basic Chemical Calculations

Q.12 Real gases approach ideal behaviour at
(a) high pressure and high temperature
(b) low pressure and high temperature
(c) high pressure and low temperature
(d) low pressure and low temperature

Q.13 In general, the specific heat of aqueous solution ________ with increase in the concentration of the solute.
(a) Increase
(b) Decrease
(c) Remains unchanged
(d) Increase then decrease

Q.14 Isotonic solutions must have the same
(a) Viscosity
(b) molar concentrations
(c) Normality
(d) Critical temperature

Q.15 If M_A and M_B are the molecular weight of component A and B respectively, then the mole fraction (X_A) and weight fraction (X_A') of component A in a binary mixture of A and B are related by
(a) $X_A' = X_A$

(b) $X_A' = \dfrac{\left(\dfrac{M_B}{M_A}\right)X_A}{1+\left[\left(\dfrac{M_B}{M_A}\right)-1\right]X_A}$

(c) $X_A' = \dfrac{M_A}{M_B}\cdot\dfrac{X_A}{(1+X_A)}$

(d) $X_A' = \dfrac{\left(\dfrac{M_A}{M_B}\right)X_A}{1+\left[\left(\dfrac{M_A}{M_B}\right)-1\right]X_A}$

Q.16 Fixed carbon content reported in the proximate analysis of solid fuels is always ________, the carbon content reported in the ultimate analysis of solid fuels.
(a) Equal to
(b) Lower than
(c) Higher than
(d) Higher than or equal to

Q.17 The concentration of SO_2 in the flue gases from a boiler was found to be 0.4 kg/m^3 at N.T.P., the concentration of SO_2 in parts per million by volume at NTP is $m \times 10^4$. Assume that the gases are perfect. The value of m is ________.

Q.18 20 kg of A is fed to a batch reactor where reaction takes place to form a product B. If M_A and M_B are the molecular weight of A and B respectively, then which of the following conclusion is correct?
(a) Total number of moles decreases as reaction proceed, if $M_A > M_B$.
(b) Total number of moles increases, if $M_A < M_B$.
(c) Total number of moles decreases as reaction proceed, if $M_A < M_B$.
(d) Total number of moles are constant and does not depend on the M_A and M_B.

Q.19 A solution is made by dissolving 1 kilo mole of solute in 2000 kg of solvent. The molality of the solution is ________. [Rounded off to 1 decimal place]

Q.20 The weight fraction of methanol in an aqueous solution is 0.64. The mole fraction of methanol (X_m) is ________. [Rounded off to 1 decimal place]

Q.21 How many kilograms of carbon are present in 64 kg of methane?
(a) 12 (b) 16
(c) 48 (d) 64

Q.22 20 gram of caustic soda is dissolved in water to prepare 500 ml of solution. What is the normality of solution?
(a) 1 N (b) 0.5 N
(c) 1.5 N (d) 2 N

Q.23 The concentration of an aqueous solution of acetic acid is specified as 30% on weight basis. What is the molality of the solution?
(a) 6.52 (b) 9.58
(c) 7.14 (d) 5.15

Q.24 An aqueous solution of sodium chloride is prepared by dissolving 25 kg of sodium chloride in 100 kg of water. Mole percentage NaCl in solution is ________. [Rounded off to two decimal places]

Q.25 Ethanol and water forms a azeotrope containing 96% ethanol by weight. What is the mole percentage ethanol in azeotrope mixture?
(a) 85.67 (b) 90.38
(c) 65.57 (d) 78.95

Q.26 An aqueous solution contains 15% ethanol by volume. What is the weight % ethanol if densities of ethanol and water are 0.79 g/cm^3 and 1.0 g/cm^3 respectively?
(a) 88.77 (b) 12.23
(c) 50.56 (d) 18.50

Q.27 The available nitrogen in the urea sample is found to be 45% by weight. What is the urea content in the sample?
(a) 96.43 kg (b) 100 kg
(c) 45 kg (d) 85.56 kg

Q.28 The nitrogen content of NH_4NO_3 sample is given as 34.5% by weight. What is the actual ammonium nitrate content of the sample?
(a) 85.56 kg (b) 34.5 kg
(c) 98.57 kg (d) 75.89 kg

Q.29 The volume occupied by 20 kg of chlorine gas at a pressure of 100 kPa and 298 K is ________ (in m^3). [Rounded off two decimal places]

Q.30 5 kg of oxygen contained in a closed container of volume 1 m^3 is heated without exceeding a pressure of 700 kPa. What is the maximum temperature of gas attained?
(a) 649 K (b) 539 K
(c) 550 K (d) 590 K

Q.31 What is the weight of sulphur dioxide in a vessel having 2 m^3 volume, the pressure and temperature being 97.33 kPa and 393 K?
(a) 5.8 kg (b) 4.8 kg
(c) 0.059 kg (d) 3.8 kg

Q.32 A certain quantity of gas contained in a closed vessel of volume 1 m^3 at a temperature of 298 K and pressure of 131.7 kPa is to be heated such that the pressure should not exceed 303.98 kPa. The temperature of gas attained is ________ (in K). [Rounded off to two decimal places]

Q.33 A sample of a gas having volume of 0.5 m^3 is compressed in such a manner so that pressure is increased by 60%. The operation is done for a fixed mass of a gas at constant temperature. The final volume of the gas is ________ (in m^3). [Rounded off to two decimal places]

Q.34 A mixture of H_2 and O_2 contains 11.1% H_2 by weight. What is the partial pressure of H_2 at 100 kPa and 303 K?
(a) 100 kPa (b) 33 kPa
(c) 67 kPa (d) 55 kPa

Q.35 equal masses of CO and N_2 are mixed together in a container at 300 K. The total pressure was found to be 405.3 kPa. What is the partial pressure of CO gas?
(a) 405.3 kPa (b) 202.65 kPa
(c) 303.56 kPa (d) 360.7 kPa

Q.36 In production of sulphur trioxide, 100 kmol of SO_2 and 200 kmol of O_2 are fed to a reactor. The product steam is found to contain 80 kmol SO_3. What is the percentage conversion of SO_2?
(a) 80 (b) 90
(c) 95 (d) 85

3. General Material Balance Equation

Linked Answer Questions (37 and 39):

Exit gases from an ethylene oxide reactor had the following analysis (mol % on dry basis) ethylene 2.3, ethylene oxide 0.9, nitrogen 79, oxygen 12.3 and CO_2 5.5.

Q.37 The value of percentage selectivity for the given process ______. [Rounded off to 2 decimal places]

Q.38 The value of overall conversion is (in %) ________. [Rounded off to 2 decimal places]

Q.39 Air to ethylene mole ratio in the feed mixture is
(a) 1 : 16.81 (b) 16.81 : 1
(c) 1 : 24.2 (d) 24.2 : 1

Q.40 20000 kg of a 5% slurry of calcium hydroxide in water is to be prepared by diluting a 20% slurry. What is the amount of water required?
(a) 500 kg (b) 1000 kg
(c) 1500 kg (d) 2000 kg

Q.41 The feed stream to a reactor contains ethylene 16%, oxygen 9%, nitrogen 31% and rest hydrogen chloride. If the ethylene flow is 5000 kg/h, the flow rate of oxygen is ________ (in kg/h). All percentage are by weight.

Q.42 Carbon dioxide is added at a rate of 10 kg/h to an air stream with 0.03 percent CO_2 and the air is sampled at a sufficient distance down stream to ensure complete mixing. If the analysis shows 0.45% v/v CO_2, what is the air flow rate?
(a) 54 kg/h (b) 1560 kg/h
(c) 1000 kg/h (d) 560 kg/h

Q.43 To ensure complete combustion, 20% excess air is supplied to a furnace burning natural gas. The gas composition (by volume) is methane 95%, ethane 5%. The moles of air required per mole of fuel is ________. [Rounded off to two decimal places]

Q.44 In the manufacture of vinyl chloride (M.W = 62.5) by the pyrolysis of dichloroethane (M.W = 99), the reactor conversion is limited to 55% to reduce carbon formation, which fouls the reactor tubes. The quantity of dichloroethane fed to the reactor to produce 5000 kg/h of vinyl chloride is ________ (in kmol/h). [Rounded off to one decimal place]

Q.45 The gas acetylene is produced according to the following reaction:

$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2$$

The number of hours of service that can be derived from 1 kg of calcium carbide in an acetylene lamp burning 0.20 m^3 gas per hour at temperature of 298 K and pressure of 100 kPa is ________. [Rounded off two decimal places]

Q.46 A gas containing 96% ethylene and 4% butenes by volume is passed through a bed of activated carbon where 95% of the original butenes are adsorbed and none of the ethylene. In five hours of continuous operation if quantity of butenes removed is 0.6 kmol, what is the molar flow rate of the feed gas to the carbon bed?
(a) 2.55 kmol/h (b) 3.06 kmol/h
(c) 4.06 kmol/h (d) 3.89 kmol/h

Q.47 A solution contains 60% ammonium nitrate, 20% urea and KCl in water by weight. What is the available nitrogen from 100 kg solution?
(a) 23.33 kg (b) 30.33 kg
(c) 35.33 kg (d) 45.56 kg

Q.48 A process gas flowing at a rate of 500 m^3/h at 100 kPa and 365 K contains H_2S with a partial pressure of 0.20 kPa. The gas passes to a scrubber in which 92% of the H_2S is removed. The H_2S removal rate is ________ (in kg/h)

Q.49 A single effect evaporator is feed with 15000 kg/h of weak liquor containing 10% caustic by weight and is concentrated to get thick liquor containing 30% by weight caustic. Water evaporated in kg/h is
(a) 5000 (b) 10000
(c) 6250 (d) 3750

Q.50 The ground nut seeds containing 50% oil and 30% solids are fed to expeller, the cake coming out of expeller is found to contain 70% solids and 10% oil. The percentage recovery of the oil is ________.

Common Data given for Questions (51 and 52):

An evaporator is fed with 10000 kg/h of a solution containing 15% NaCl, 10% NaOH and rest water. In the operation, water is evaporated and NaCl is precipitated as crystals. The thick liquor leaving the evaporator contains 50% NaOH, 5% NaCl and rest water.

Q.51 kg/h water evaporated is
(a) 6600 kg/h (b) 2000 kg/h
(c) 1400 kg/h (d) 5000 kg/h

Q.52 kg/h salt precipitated is
(a) 5600 kg/h (b) 2000 kg/h
(c) 1400 kg/h (d) 2500 kg/h

Answers Process Calculation

1.	(b, c)	2.	(a)	3.	(c, d)	4.	(d)	5.	(a, c, d)	6.	(1)	7.	(0)
8.	(2)	9.	(2)	10.	(a)	11.	(b)	12.	(b)	13.	(b)	14.	(b)
15.	(d)	16.	(b)	17.	(14)	18.	(c)	19.	(0.5)	20.	(0.5)	21.	(c)
22.	(a)	23.	(c)	24.	(7.13)	25.	(b)	26.	(b)	27.	(a)	28.	(c)
29.	(6.98)	30.	(b)	31.	(d)	32.	(687.82)	33.	(0.31)	34.	(c)	35.	(b)
36.	(a)	37.	(24.66)	38.	(61.34)	39.	(b)	40.	(c)	41.	(2813)	42.	(b)
43.	(11.86)	44.	(145.5)	45.	(1.93)	46.	(b)	47.	(b)	48.	(1.03)	49.	(b)
50.	(91.43)	51.	(a)	52.	(c)	53.	(b)	54.	(558.82)	55.	(b)	56.	(b)
57.	(b)	58.	(b)	59.	(b)	60.	(b)	61.	(c)	62.	(18.28)	63.	(c)
64.	(c)	65.	(d)	66.	(a)	67.	(b)	68.	(b)	69.	(0.97)	70.	(b)
71.	(b)	72.	(b)	73.	(b)	74.	(94.27)	75.	(c)	76.	(c)	77.	(0.615)
78.	(b)	79.	(a)	80.	(b)	81.	(a)	82.	(d)	83.	(d)	84.	(b)
85.	(a)	86.	(b)	87.	(a, b, c, d)	88.	(b)	89	(5703)	90.	(10087)	91.	(107.82)
92.	(266)	93.	(2.42)	94.	(b)	95.	(b)	96.	(a)	97.	(a)	98.	(280)
99.	(35)	100.	(13025)	101.	(2694)	102.	(25.43)	103.	(379)	104.	(38)	105.	(16.72)
106.	(a)	107.	(58)	108.	(46)	109.	(c)	110.	(a, b, c)	111.	(d)	112.	(83.2)
113.	(26)	114.	(664.75)	115.	(a, b, c, d)	116.	(a)	117.	(c)	118.	(d)	119.	(c)
120.	(0)	121.	(11.7)	122.	(50)	123.	(37.2)	124.	(32.7)	125.	(3.85)	126.	(4)
127.	(68)	128.	(14)	129.	(505.6)	130.	(a)						

Explanation Process Calculation

2. (a)

As we increase the pressure of a gas at fixed temperature, the collision frequency increases and thus solubility goes up.

3. (c, d)

- If degree of freedom is negative then the operation is termed as overspecified.
- If the degree of freedom is positive, then the operation is termed as under specified.

6. (1)

∴ Degree of freedom (F) is given by

$$F = C - P + 2$$

where, $C = 1, \quad P = 2$

∴ $F = 1 - 2 + 2 = 1$

7. (0)

∴ $F = C - P + 2$

F = Degree of freedom

where, $C = 1$ (Component)

$P = 3$ (Phases)

∴ $F = 1 - 3 + 2 = 0$

8. (2)

∴ $F = C - P + 2$

where, $C = 2, \quad P = 2$

∴ $F = 2 - 2 + 2 = 2$

9. (2)

∴ $F = C - P + 2$

where, $C = 2, \quad P = 2$

∴ $F = 2 - 2 + 2 = 2$

11. (b)

$$M_{avg} = \sum M_i x_i$$
$$M_{avg} = M_{N_2} \cdot x_{N_2} + M_{CO_2} \cdot x_{CO_2}$$
$$31 = 28x_{N_2} + 44x_{CO_2}$$
$$x_{N_2} + x_{CO_2} = 1$$
$$x_{CO_2} = 1 - x_{N_2}$$
$$31 = 28x_{N_2} + 44(1 - x_{N_2})$$
$$16x_{N_2} = 13$$
$$x_{N_2} = 0.8125$$

Partial pressure of $N_2 = x_{N_2} \cdot P$

$$= 0.8125 \times 101.325 = 82.33 \text{ kPa}$$

14. (b)

Isotonic solutions refers to two solution having the same osmotic pressure/or concentration across a semi-permeable membrane.

17. (14)

Concentration of SO_2 in the flue gas at NTP

$= 0.4 \text{ kg/m}^3$

Molecular weight,

$\Rightarrow$ $SO_2 = 64$

$\therefore$ Concentration of SO_2 in ppm:

$$= \frac{0.4}{64} \times 22.4 \times 10^6 = 0.14 \times 10^6 \text{ ppm}$$

18. (c)

(let) $aA \to bB$

$\therefore$ As mass is always conserved therefore

$$aM_A = bM_A$$
$$\frac{n_b}{n_a} = \frac{M_A}{M_B}$$

Thus, $M_B > M_A$, then $n_b < n_a$ where n = number of moles.

19. (0.5)

$$\therefore \quad \text{Molality} = \frac{\text{Number of moles of solute}}{\text{Mass of solvent in kg}}$$

$$\text{Molality} = \frac{1000}{2000} = 0.5$$

20. (0.5)

Let 100 g of total mixture, i.e.

64 g $\to$ Methanol

36 g $\to$ H_2O (water)

M.W. of methanol = 32 g/mol,

MW of H_2O = 18 g/mol

$$\text{Mole of } CH_3OH = \frac{64}{32} = 2 \text{ moles}$$

$$\text{Mole of } H_2O = \frac{36}{18} = 2 \text{ moles}$$

$$\text{Mole fraction of methanol} = \frac{2}{4} = 0.5$$

21. (c)

In 16 kg CH_4, 12 kg of carbon are present

So amount of carbon present in 64 kg of methane

$$= \frac{12}{16} \times 64 = 48 \text{ kg}$$

22. (a)

Basis: 500 ml of solution

Molecular weight of NaOH = 40

$$\text{Equivalent weight of NaOH} = \frac{40}{1} = 40$$

$$\text{Gram equivalents of NaOH} = \frac{20}{40} = 0.5 \text{ g.eq}$$

$$\text{Normality (N)} = \frac{\text{g eq. of NaOH}}{\text{Volume of solution in '}l\text{'}}$$

$$= \frac{0.5}{0.5} = 1$$

23. (c)

Basis: 100 kg of solution

Amount of acetic acid = 30 kg

Amount of water (solvent) = 70 kg

Molecular weight of CH_3COOH = 60

$$\text{Moles of acetic acid} = \frac{30 \times 10^3}{60} = 500 \text{ mol}$$

$$\text{Molality of solution} = \frac{\text{Moles of acetic acid}}{\text{kg of solvent}}$$

$$= \frac{500}{70} = 7.142$$

24. (7.13)

Amount of solution = 125 kg

$$\text{Moles of NaCl} = \frac{25}{58.5} = 0.427 \text{ kmol}$$

$$\text{Moles of } H_2O = \frac{100}{18} = 5.56 \text{ kmol}$$

Total moles of solution = 0.427 + 5.56

= 5.987 kmol

$$\text{Mole \% NaCl in solution} = \frac{\text{kmol NaCl}}{\text{kmol solution}} \times 100$$

$$= \frac{0.427}{5.987} \times 100 = 7.13$$

25. (b)

Basis: 100 kg of ethanol-water mixture

It contains 96 kg of ethanol and 4 kg of water

$$\text{Moles of ethanol} = \frac{96}{46} = 2.087 \text{ kmol}$$

$$\text{Moles of water} = \frac{4}{18} = 0.222 \text{ kmol}$$

Moles of azeotrope mixture = 2.087 + 0.222

= 2.309 kmol

Mole % ethanol in azeotrope mixture

$$= \frac{2.087}{2.309} \times 100 = 90.38\%$$

26. (b)

Basis: 100 cm^3 of aqueous solution

Volume of ethanol in the solution = 15 cm^3

Volume of water in the solution = 85 cm^3

Amount of ethanol in the solution

= 15 × 0.79 = 11.85 g

Amount of water in the solution = 85 × 1 = 85 g

Weight % ethanol in the solution

$$= \frac{11.85}{11.85 + 85} \times 100 = 12.23$$

27. (a)

Basis: 100 kg of urea sample

Amount of N in sample = 0.45 × 100 = 45 kg

60 kg urea contains = 28 kg N

$$\text{Actual urea in sample} = \frac{60}{28} \times 45 = 96.43 \text{ kg}$$

28. (c)

Basis: 100 kg of sample

Amount of N in the sample = 34.5 kg

M.W. of NH_4NO_3 = 80

On the weight basis

80 kg NH_4NO_3 = 28 kg N

Amount of NH_4NO_3 in sample

$$= \frac{80}{28} \times 34.5 = 98.57 \text{ kg}$$

29. (6.98)

$$\text{Moles of } Cl_2 \text{ gas} = \frac{20}{71} = 0.2817 \text{ kmol}$$

Ideal gas equation

$$PV = nRT$$

$$V = \frac{nRT}{P}$$

$$= \frac{0.2817 \times 8.314 \times 298}{100}$$

$$V = 6.98 \text{ m}^3$$

30. (b)

$$\text{Moles of } O_2 = \frac{5}{32} = 0.1562 \text{ kmol}$$

$$PV = nRT$$

$$T = \frac{PV}{nR}$$

So, $$T = \frac{700 \times 1}{0.1562 \times 8.314} = 539 \text{ K}$$

31. (d)

$$PV = nRT$$

$$n = \frac{PV}{RT} = \frac{97.33 \times 2}{8.314 \times 393}$$

$$n = 0.0596 \text{ kmol}$$

$$\text{Weight of } SO_2 = 0.0596 \times 64 = 3.8144 \text{ kg}$$

32. (687.82)

A gas at 298 K in closed vessel

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

As vessel being closed

$$V_1 = V_2$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{131.7}{298} = \frac{303.98}{T_2}$$

$$T_2 = 687.82 \text{ K}$$

33. (0.31)

Let initial pressure = P_1

So final pressure (P_2) = 1.6P_1

Temperature and mass are constant, therefore

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{P_1 \times 0.5}{1.6 P_1} - 0.3125 \text{ m}^3$$

34. (c)

Basis: 100 kg of gas mixture

$$\text{Moles of } H_2 = \frac{11.1}{2} = 5.55 \text{ kmol}$$

$$\text{Moles of } O_2 = \frac{88.9}{32} = 2.78 \text{ kmol}$$

$$\text{Mole fraction of } H_2 = X_{H_2}$$

$$= \frac{5.55}{5.55+2.78} = 0.67$$

$$\text{Partial pressure of } H_2 = X_{H_2} \cdot P$$

$$= 0.67 \times 100 = 67 \text{ kPa}$$

35. (b)

$$\text{Moles of CO} = \frac{M_1}{28}, \quad \text{Moles of } N_2 = \frac{M_1}{28}$$

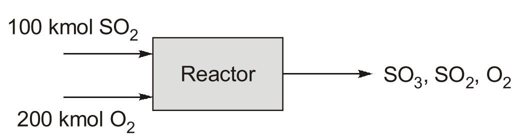
$$\text{Total moles of the gas mixture} = \frac{2M_1}{28}$$

$$\text{Mole fraction of CO} = \frac{\frac{M_1}{28}}{\frac{2M_1}{28}} = 0.5$$

$$\text{Partial pressure of CO} = x_{CO} \cdot P$$

$$= 0.5 \times 405.3 = 202.65 \text{ kPa}$$

36. (a)



$$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$$

For 80 kmol $SO_3 \rightarrow SO_2$ reacted is

$$= 80 \times \frac{1}{1} = 80 \text{ kmol}$$

$$\% \text{ conversion of } SO_2 = \frac{\text{kmol } SO_2 \text{ reacted}}{\text{kmol } SO_2 \text{ charged}} \times 100$$

$$= \frac{80}{100} \times 100 = 80\%$$

37. (24.66)

Basis 100 mol of dry exit gases,

Reactions:

$$C_2H_4 + \frac{1}{2}O_2 \rightarrow C_2H_4O$$

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

$\therefore$ Moles of H_2O produce = moles of CO_2 produced = 5.5

Total number of moles leaving the reactor

$$= 100 + \text{moles of } H_2O$$

$$= 100 + 5.5 = 105.5$$

Now, analysis of exit gases on wet basis

$$\text{Ethylene} = \frac{2.3}{105.5} \times 100 = 2.18\%$$

$$\text{Ethylene oxide} = \left(\frac{0.9}{105.5}\right) \times 100 = 0.853$$

$$\therefore \% \text{ selectivity} = \frac{C_2H_4 \text{ used for desirable reaction}}{\text{Total } C_2H_4 \text{ reacted}}$$

$$= \frac{0.853}{0.853+0.5 \times 5.213} \times 100 = 24.66\%$$

Here 5.213 is percent composition of CO2 inert gases.

38. (61.34)

$$\% \text{ overall conversion} = \frac{\text{Total } C_2H_4 \text{ reacted}}{C_2H_4 \text{ in feed}} \times 100$$

$$= \frac{0.853 + 0.5 \times 5.213}{0.853 + 0.5 \times 5.213 + 2.18} \times 100 = 61.34\%$$

39. (b)

$$\text{Ethylene in feed} = 0.853 + 0.5 \times 5.213 + 2.18$$

$$= 5.6395 \text{ mol}$$

$$\text{Air in feed} = \frac{74.88}{0.79} = 94.785 \text{ mol}$$

$\therefore$ Now air to ethylene mole ratio in feed is

$$= \frac{94.785}{5.6395} : 1 = 16.81 : 1$$

40. (c)

Let the unknown quantities of the 20% slurry and water be X and Y, respectively.

Material balance on $Cu(OH)_2$

$$X(0.2) = 2000 \times 0.05$$

So, $X = 500$ kg

Balance on water

$$X(0.8) + Y = 2000 \times 0.95$$

$$Y = 1500 \text{ kg}$$

41. (2813)

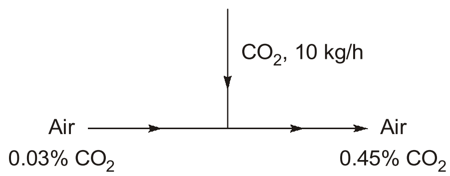
$$\% \text{ HCl} = 100 - (16 + 9 + 31) = 44$$

$$\text{Percentage ethylene} = 16 = \frac{5000}{\text{Total}} \times 100$$

$$\text{Total flow} = 5000 \times \frac{100}{16} = 31250 \text{ kg/h}$$

$$\text{So, Oxygen flow} = \frac{9}{100} \times 31250 = 2813 \text{ kg/h}$$

42. (b)



Basis: kmol/h, as percentage are by volume

$$\text{kmol/h } CO_2 \text{ introduced} = \frac{10}{44} = 0.2273$$

Let X be the air flow

Balance an CO_2, the tie component

$$CO_2 \text{ in} = CO_2 \text{ out}$$

$$0.0003x + 0.2273 = 0.0045X$$

$$X(0.0045 - 0.0003) = 0.2273$$

$$X = \frac{0.2273}{0.0042} = 54 \text{ kmol/h}$$

$$X = 54 \times 29 = 1560 \text{ kg/h}$$

43. (11.86)

Basis: 100 mol gas, as the analysis is volume percentage.

Reaction:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

$C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O$

Stoichiometric moles of O_2 required

$$= 95 \times 2 + 5 \times 3.5 = 207.5$$

With 20% excess, moles of O_2 required

$$= 1.2 \times 207.5 = 249$$

$$\text{Moles of air} = \frac{249}{0.21} = 1185.7$$

$$\text{As per mole of fuel} = \frac{1185.7}{100} = 11.86 \text{ mol}$$

44. (145.5)

Reaction: $C_2H_4Cl_2 \rightarrow C_2H_3Cl + HCl$

$$\text{kmol/h vinyl chloride produced} = \frac{5000}{62.5} = 80$$

From stoichiometric equation, 1 kmol DCE produces 1 kmol VC. Let X be DCE feed in kmol/h

$$\text{Percent conversion} = \frac{80}{X} \times 100 = 55$$

$$X = \frac{80}{0.55} = 145.5 \text{ kmol/h}$$

45. (1.93)

$$\text{Moles of } CaC_2 = \frac{1}{64} = 0.01562 \text{ kmol}$$

From reaction

$$1 \text{ kmol } CaC_2 = 1 \text{ kmol } C_2H_2$$

Moles of C_2H_2 produced = 0.01562 kmol

$$PV = nRT$$

Volume of C_2H_2 gas produced

$$= \frac{0.01562 \times 8.314 \times 298}{100} = 0.386 \text{ m}^3$$

Number of hours of service

$$= \frac{\text{Volume of acetylene gas}}{\text{Burning rate of acetylene}}$$

$$= \frac{0.386}{0.20} = 1.935 \text{ h}$$

46. (b)

$$\text{Butenes removed} = \frac{0.6}{5} = 0.12 \text{ kmol/h}$$

Let y be the molar flow rate of gas to the carbon bed

Butenes in the gas fed = $0.04y$ kmol/h

$$\text{Butenes adsorbed} = 0.98 \times 0.04y$$

$$= 0.0392y \text{ kmol/h}$$

$$0.0392y = 0.12$$

$$y = \frac{0.12}{0.0392} = 3.06 \text{ kmol/h}$$

Molar flow rate of the gas to carbon bed

$$= 3.06 \text{ kmol/h}$$

47. (b)

Basis: 100 kg of solution

It contains 60 kg ammonium nitrate and 20 kg urea.

$$1 \text{ kmol } NH_4NO_3 = 2 \text{ katom N}$$

$$80 \text{ kg } NH_4NO_3 = 28 \text{ kg N}$$

$$\text{Nitrogen available from } NH_4NO_3 = \frac{28}{80} \times 60$$

$$= 21 \text{ kg}$$

$$1 \text{ kmol } NH_4CONH_2 = 2 \text{ katom N}$$

$$60 \text{ kg } NH_2CONH_2 = 28 \text{ kg N}$$

$$\text{Nitrogen available from area} = \frac{28}{60} \times 20 = 9.33 \text{ kg}$$

Total nitrogen available from solution

$$= 21 + 9.33 = 30.33 \text{ kg}$$

48. (1.03)

Partial pressure of H_2S = 0.20 kPa

Pressure fraction of $H_2S = \dfrac{0.20}{100} = 0.2 \times 10^{-2}$

For ideal gas

Pressure fraction = Mole fraction = 2×10^{-3}

Molar flow rate of process gas

$$= \frac{500 \times 100}{8.314 \times 365} = 16.47 \text{ kmol/h}$$

H_2S in the process gas = $2 \times 10^{-3} \times 16.47$

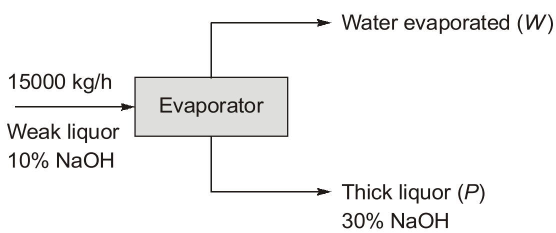
= 0.033 kmol/h

H_2S removed in the scrubber = 0.92×0.033

= 0.03 kmol/h

H_2S removal rate = $0.03 \times 34 = 1.03$ kg/h

49. (b)



Overall material balance

$$15000 = W + P \qquad \ldots(i)$$

Material balance of NaOH

$$15000 \times 0.1 = P \times 0.30$$

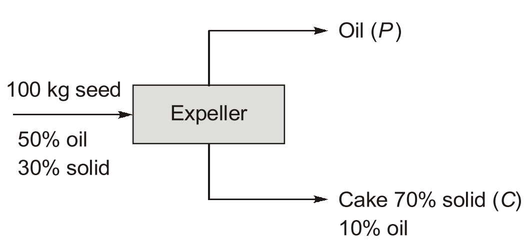
$$P = \frac{1500}{0.30} = 5000 \text{ kg/h}$$

From equation (i)

$$15000 = W + 5000$$

$$W = 10000 \text{ kg/h}$$

50. (91.43)



Overall material balance

$$100 = P + C$$

Material balance of solid

$$0.30 \times 100 = 0.70 \times C$$

$$C = 42.85 \text{ kg}$$

Material balance of oil

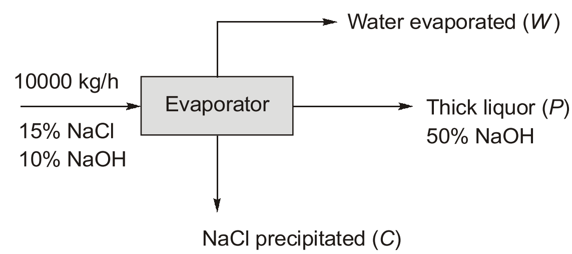
$$0.50 \times 100 = 0.10 \times C + P$$

(Oil recovered) P = 45.71 kg

$$\% \text{ recovery of the oil} = \frac{\text{kg oil recovered}}{\text{kg oil in seeds}} \times 100$$

$$= \frac{45.71}{50} \times 100 = 91.43\%$$

51. (a)



Overall material balance

$$10000 = W + P + C$$

Material balance of NaOH

$$0.10 \times 10000 = P \times 0.50$$

$$P = 2000 \text{ kg/h}$$

Material balance of NaCl

$$0.15 \times 10000 = 0.05 \times 2000 + C$$

$$C = 1400 \text{ kg/h}$$

We have,

$$P + W + C = 10000$$

$$1400 + 2000 + W = 10000$$

$$W = 6600 \text{ kg/h}$$

52. (c)

NaCl precipitated

$$0.15 \times 10000 = 0.05 \times P + C$$

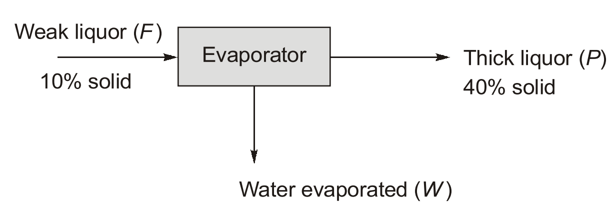
where, P = 2000 kg/h

$$C = 1500 - 100 = 1400 \text{ kg/h}$$

53. (b)

Case I:

Basis: 100 kg/h of solid handling capacity of the evaporator



Material balance of solids

$$0.1 \times F = P \times 0.4$$

Given, $0.1 \times F = 100$

So, $P = \dfrac{100}{0.4} = 250$ kg/h