JEPPIAAR ENGINEERING COLLEGE DEPARTMENT OF BIOTECHNOLOGY BATCH (2017-2021): II YEAR / III SEM



QUESTION BANK

BT 8301 STOICHIOMETRY

[REGULATION 2017]

PREPARED BY

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BT8301 STOICHIOMETRY

OBJECTIVES:

 \Box The course aims to develop skills of the students in the area of Chemical Engineering with Emphasis in process calculations and fluid mechanics.

 $\hfill\square$ This will enable the students to perform calculations pertaining to processes and operations.

UNIT I BASIC CHEMICAL CALCULATIONS (9 + 6)

Dimension – Systems of units esp. engineering FPS, Engineering MKS & SI systems – Conversion from one system to the other – composition of mixtures and solutions – mass fraction, mass %, mole fraction, mole %, mass ratios, molarity, molality, normality, ppm, composition by density.

UNIT II IDEAL AND ACTUAL GAS EQUATIONS (9+6)

Ideal and actual gas equations, Vander Walls, compressibility factor equations, Application to pure gas & gas mixtures – partial pressures, partial volumes – Air-water vapour systems, Humidity, Molar Humidity, Relative Humidity, % Saturation, humid Volume – Humidity chart – wet, Dry bulb, Dew point temperatures, pH of solutions, Vapor pressure.

UNIT III MATERIAL BALANCE (9 + 6)

Material balance concept – overall & component – material balance applications for evaporator, gas absorber without reaction, Distillation (Binary system), Liquid extraction, solid-liquid extraction, drying, crystallization, Humidification, Reverse Osmosis separation and Mixing Recycle and Bypass illustration

UNIT IV ENERGY BALANCE (9 + 6)

General energy balance equation for open systems, closed system sensible heat calculation, Heat required for phase change thermo chemistry, application of steam tables, Saturated and

Superheated steam application in bioprocess

UNIT V CHEMICAL REACTION (9 + 6)

Chemical Reaction-Limiting, excess component, Fractional conversion, Percent conversion, Fractional yield in multiple reactions. Simple problems, Combustion Reactions.

TOTAL: 75 PERIODS

OUTCOMES:

Upon success completion of this course, the students will be able to:

□ Solve problems related to units and conversions and fit the given data using the methodologies

□ Solve problems related to material and energy balance concepts & design reactors for

biochemical processes

□ Apply their knowledge in the field of biochemical engineering from the principles of

Thermodynamics

TEXT BOOKS:

1. Bhatt B.I & SB Thakore, Stoichiometry - Fifth edition Tata McGraw Hill 2012

2. Geankoplis C.J. "Transport process & Separation process Principles 4th edition-PHI 2006. **REFERENCES:**

1. McCabe W.L & J.C.Sonith & P.Harriot "Unit operations of chemical Engineering" 6thEdn McGraw Hill 2001

2. Robert W.Fox, Alan T.McDonald & Philip J.Pritchard "Introduction to FluidMechanics" 6th Edn John Wiley & Sons 2003.

3. Himmelblau D.M "Basic principles & Calculations in Chemical Engineering" 6th edn PHI 2006

LESSON PLAN

S. No.	Title	Reference Book	Page No.	
	UNIT I – BASIC CHEMICAL CALCULATIONS (9+6)			
1.	Dimension – Systems of units esp. engineering FPS,– mass fraction,	B.I.Bhatt S.M.Vora, Stoichiometry	1-15	
2.	Engineering MKS & SI systems –	B.I.Bhatt S.M.Vora, Stoichiometry	15-20	
3.	Conversion from one system to the other – composition of mixtures and solutions	B.I.Bhatt S.M.Vora, Stoichiometry	20-26	
4.	mass %, mole fraction, mole %, mass ratios, molarity, molality, normality, ppm, composition by density.	B.I.Bhatt S.M.Vora, Stoichiometry	26-35	
	UNIT II – IDEAL AND ACTUAI	L GAS EQUATIONS (9+6)		
1.	Ideal and actual gas equations	B.I.Bhatt S.M.Vora, Stoichiometry	35-38	
2.	Vander Walls Compressibility factor equations	B.I.Bhatt S.M.Vora, Stoichiometry	38-42	
3.	Applications to pure gas and gas mixtures	B.I.Bhatt S.M.Vora, Stoichiometry	42-46	
4.	Partial pressures, partial volumes, Air-Water Vapour Systems	B.I.Bhatt S.M.Vora, Stoichiometry	46-50	
5.	Humidity, Molar humidity, Relative humidity, % Saturation, Humid volume	B.I.Bhatt S.M.Vora, Stoichiometry	340-350	
6.	Humidity chart – wet, dry bulb, dew point temperatures	B.I.Bhatt S.M.Vora, Stoichiometry	351-360	
UNIT III - MATERIAL BALANCES (9+6)				
1.	Material balance concept – overall and component	B.I.Bhatt S.M.Vora, Stoichiometry	112-120	
2.	Material Balance applications for evaporator	B.I.Bhatt S.M.Vora, Stoichiometry	121-138	
3.	Gas absorber without reaction	B.I.Bhatt S.M.Vora,	176-223	

		Stoichiometry	
4.	Distillation, Liquid Extraction, Drying, Crystallization, Humidification	B.I.Bhatt S.M.Vora, Stoichiometry	318-331
5.	Reverse Osmosis Separation and Mixing Recycle, Bypass Illustration	B.I.Bhatt S.M.Vora, Stoichiometry	332-340
	UNIT IV – ENERGY E	BALANCE (9+6)	1
1.	General energy balance equation for open system, heat required for phase change	B.I.Bhatt S.M.Vora, Stoichiometry	243-278 389-397
2.	Application of steam tables	B.I.Bhatt S.M.Vora, Stoichiometry	597-610
3.	Saturated and superheated steam application in Bioprocesses	Technical paper	
1.	Chemical Reaction-Limiting, excess component,	Geankoplis C.J. "Transport process & Separation process Principles	151-154
2.	Fractional conversion, Percent conversion,	Geankoplis C.J. "Transport process & Separation process Principles 4th edition-PHI 2006	165-174
3.	Fractional yield in multiple reactions.	Geankoplis C.J. "Transport process & Separation process Principles 4th edition-PHI 2006	181-210
			144-153
4.	Simple problems, Combustion Reactions.	Geankoplis C.J. "Transport	154-160

BT8301 STOICHIOMETRY

UNIT I – BASIC CHEMICAL CALCULATIONS

PART A

- 1. Define Average molecular weight. The average molecular weight (or molecular weight distribution) describes the relationship between the number of moles of each component (N_i) and the molar mass (M_i) of that component.
- 2. Give the S.I.units and dimensions of mass velocity. (NOV/DEC 2012) Mass velocity:
 S.I.unit of mass velocity (G) = kg/m².s Dimension = ML⁻²T⁻¹
- 3. Give the S.I.units and dimensions of pressure. (NOV/DEC 2012)
 Pressure:
 S.I.unit of Pressure (P) = N/m² (or) Pa
 Dimension = ML⁻¹T⁻²
- Define the term 'Celsius Temperature'. (NOV/DEC 2011) It is the unit of measurement of temperature. It corresponds to the Kelvin temperature minus 273.15. it defines the freezing point as 0°C (273.15K) and the boiling point as 373.15 K (100°C)

 $^{\circ}\text{C} + 273.15 = ^{\circ}\text{K}$

5. What is 'Nondecimal Unit'? (NOV/DEC 2011)

Measurements in non-metric (non-base 10) measurements, e.g. feet, inches and pre-decimal (pre-1971) UK currency.

Non-base 10 units difficult to work with for statistical analysis unless, either convert to metric or convert the overall measurement into a single unit (e.g. convert pounds, shilling and pence to just pence or feet and inches to just inches. If comparing a dataset with metric measurements with a dataset with imperial measurements it is preferable to convert to metric for comparisons.

6. Convert 15 Btu/hr.ft² °F to cal/s.cm² °C. (NOV/DEC 2011)

 $= \frac{15Btu}{hr.ft^{2}\circ F} \times \frac{252Cal}{1Btu} \times \frac{1hr}{3600s} \times \frac{1ft^{2}}{0.0929m^{2}} \times \frac{1m^{2}}{10^{4}cm^{2}} \times \frac{1.8^{\circ}F}{1^{\circ}C}$ = 20.34 X 10⁻⁴ cal/s.cm² °C 15 Btu/hr.ft² °F = **20.34 X 10⁻⁴ cal/s.cm²** °C

7. What is the volume of 25 kg of chlorine gas at NTP? (NOV/DEC 2011) Number of moles = $\frac{Mass}{Molecularweight} = \frac{25kg}{71kg/kgmol} = 0.352$ kg mol Number of moles = 0.352 kgmol

1 kg moles of Cl₂ gas occupies 22.414 litres at NTP = 0.352×22.414

$$V = 7.89 \text{ m}^3$$

Volume of 25 kg Cl_2 gas occupies at NTP =7.89 m³

8. Explain the law of conservation of energy for unsteady system. (APR/MAY 2010) Law of conservation of energy:

Energy can neither be created nor be destroyed. It can only be converted from one form to another form.

- 9. Convert 5 cal/gm °C to kJ/g °C and 875°F to Kelvin. (NOV/DEC 2010)
 - (i) $5 \text{ cal/gm} ^{\circ}\text{C} = 5 \text{ x } 4.184 \text{ J/g} ^{\circ}\text{C} = 20.92 \text{ J/g} ^{\circ}\text{C} = 0.02092 \text{ kJ/ g} ^{\circ}\text{C}$ $5 \text{ cal/gm} ^{\circ}\text{C} = 0.02092 \text{ kJ/ g} ^{\circ}\text{C}$
 - (ii) $875^{\circ}F = \frac{5}{9}(875 32)^{\circ}C = 0.55 (843) = 468.35^{\circ}C$ $^{\circ}K = ^{\circ}C + 273 = 468.35 + 273 = 741.35 K$ $875^{\circ}F = 741.35 K$
- 10. Write down the value of gas constant in SI and CGS units. (NOV/DEC 2010) Value of gas constant in SI units:

 $\mathbf{R} = \mathbf{0.083} \text{ bar m}^3 / \text{kmole K}$ Value of gas constant in CGS units: $\mathbf{R} = \mathbf{0.085} \text{ kgf m}^3 / \text{kmole K}$

11. State the SI units of pressure and Energy. (NOV/DEC 2009) SI units of pressure: The unit of pressure is N/ m² 1 Pa = 1 N/ m²

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1 atm = 760 mm Hg

1 atm = 1.01325 bar

1 bar = 10^5 Pa

SI units of Energy: 1 Joule =1 N.m

1 Joule =1 kg.m<sup>2</sup>/s<sup>2</sup>

1 Joule = 10^7 erg
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12. State the law of conservation of mass. (NOV/DEC 2009) (NOV/DEC 2007) Conservation of mass:

The total mass of various compounds remain unchanged during an unit operation or a chemical reaction.

13. Convert 50°F to °R (NOV/DEC 2009)

50°F to °R: °R = 459.63 +°F = 459.63 + 50 = 509.63 50°F = 509.63°R

14. Convert 50°F to Kelvin scale. (NOV/DEC 2009)

$$^{\circ}C = \frac{1}{1.8} (^{\circ}F - 32) = \frac{1}{1.8} (50 - 32) = 10^{\circ}C$$

$${}^{\circ}K = {}^{\circ}C + 273 = 10 + 273 = 283K$$

 $50{}^{\circ}F = 283K$

- 15. What are the basic quantities used in SI system? (NOV/DEC 2008) Basic quantities used in SI system
 - (i) Mass (kg)
 - (ii) Length (m)
 - (iii) Time (s)
 - (iv) Temperature (K)

16. Give some examples for derived quantities. (NOV/DEC 2008)

Examples of derived quantities

- (i) Force (F)
- (ii) Pressure (P)
- (iii) Density (ρ)
- (iv) Viscosity (μ)
- 17. Define molality and molarity.

Molality:

Molality is defined as the ratio of moles of solute to the mass of solvent.

Molarity :

Molarity is defined as the ratio of moles of solute to litre of solution (volume of solution).

18. Convert 11°C to °F, °K.

- (i) $11^{\circ}C : {}^{\circ}F = \frac{9}{5} {}^{\circ}C + 32 = \frac{9}{5} (11) + 32 = 19.8 + 32 = 51.8^{\circ}F$ (ii) ${}^{\circ}K = {}^{\circ}C + 273 = 11 + 273 = 284$ $11^{\circ}C = 284 \text{ K}$
- 19. Convert 1 btu to Calories and Joules.

$$1 \text{ cal} = 4.184 \text{ J}$$

$$1 Btu = 252 x 4.184 J = 1054.36 J$$

- 1 Btu = 1054.36 J
- 20. Name various systems of units.

There are three system of units.

- (i) System international (SI)
- (ii) English Engineering units (FPS)
- (iii) Metric Engineering units (CGS/MKS)

21. What are the basic quantities used in the SI system and CGS system of units? SI system

Quantities	Unit	Symbol	
Length	metre	m	
Mass	kilogram	kg	
Time	second	S	
Derived unit			
Force	Newton	Ν	

CGS system

Quantities	Unit	Symbol	
Length	centimetre	cm	
Mass	gram	gr	
Time	second	S	
Derived unit			
Force	dyne	dyne	

22. Give the dimensions and units for pressure and force in S.I.system. **Pressure:**

S.I.unit of pressure (P) = N/m² (or) Pa Dimension = $ML^{-1}T^{-2}$ Force: S.I.unit of force (F) = Newton (N) Dimension = MLT^{-2}

PART B

- (i) The available nitrogen in the urea sample is found to be 45% by weight. Calculate the actual urea content in the sample. (NOV/DEC 2016) (Stoichiometry by Bhatt & Vora, Pg.No.23)
 (ii) A natural gas has the following composition by volume Methane -83.5%, Ethane 12.5% and Nitrogen 4%. Calculate the composition in (1) Mole% (2) Weight % (3) Average molecular weight. (NOV/DEC 2016) (Class notes)
- 2. Describe in detail various system of units and explain how it is being derived. [NOV/DEC 2013] [NOV/DEC 2010](Stoichiometry by Bhatt & Vora, Pg.No.15-18)

- 3. Find the equivalent weight of HCl, NaOH, Na₂CO₃, H₂SO₄, H₃PO₄, CaCl₂, FeCl₃, KMnO₄. [NOV/DEC 2015] (Stoichiometry by Bhatt & Vora, Pg.No.20-21)
- 4. A chemist is interested in preparing 500 ml of 1 normal, 1 molar and 1 molal solution of H₂SO₄. Assuming the density of H₂SO₄ solution to be 1.075 g/cm³, calculate the quantities of H₂SO₄ to be taken to prepare these solutions. [NOV/DEC 2015] (Stoichiometry by Bhatt & Vora, Pg.No.28)

UNIT II – IDEAL AND ACTUAL GAS EQUATIONS PART A

- State Raoults law. (NOV/DEC 2016)
 It states that the vapor pressure of the solvent in the solution is directly proportional to the mole fraction of the solvent.
 (Vapor pressure of the solvent in the solution) = (vapor pressure of pure solvent) x (mole fraction of the solvent)
- Define relative humidity(APR/MAY 2015) (NOV/DEC 2012,2007) Relative humidity is defined as the ratio of the partial pressure of water vapour in air to the vapour pressure of water.

% Relative humidity =
$$\frac{p_A}{p_{AS}} \times 100$$

3. Define percentage humidity. (APR/MAY 2015) (NOV/DEC 2012,2007)

Percentage humidity is defined as the ratio of humidity under given condition to the humidity under the saturated condition.

% humidity =
$$\frac{H}{H_s} = \frac{H_m}{H_{ms}} \times 100$$

H- humidity , H_S –humidity under saturated condition H_m -molal humidity , H_{ms} – molal humidity at saturation

- 4. Write the numerical quantity of Universal Gas Constant, R in: L Torr k^{-1} mol⁻¹ (APR/MAY 2015)
 - (a) Universal gas constant R = 0.08215 atm.m³ / kg.mol.K $0.0825 \frac{(atm.m^3)}{kgmol.K} \times \frac{760mmHg}{1atm} \times \frac{1torr}{1mmHg} \times \frac{1000L}{1m^3} \times \frac{1kg}{1000g}$ R= 62.434 L Torr k⁻¹ mol⁻¹
- 5. Write the numerical quantity of Universal Gas Constant, R in: Ft³ psi R⁻¹ lb-mol⁻¹ (APR/MAY 2015)

(b)
$$0.0825 \frac{(atm.m^3)}{kgmol.K} \times \frac{14.697Psi}{1atm} \times \frac{1ft^3}{(0.3048)^3 m^3} \times \frac{0.4535kg}{1lb} \times \frac{1^\circ K}{1.8^\circ R}$$

R= 10.74 Ft³ psi R⁻¹ lb-mol⁻¹

6. If a vacuum gauge shows 300 mm pressure, what is the absolute pressure in bar.(NOV/DEC 2014)

Absolute pressure:

 $\begin{array}{ll} P_{gauge} = 300 \text{mm Hg} & [1 \text{ bar} = 760 \text{ mm Hg}] \\ P_{atm} &= 760 \text{ mm Hg} \\ P_{absolute} = P_{gauge} + P_{atm} \\ &= (300 + 760) \text{ mm Hg} = 1060 \text{ mm Hg} \\ &= 1060/760 = 1.395 \text{ bar} \\ P_{atm} &= 1.395 \text{ bar} \end{array}$

7. If molal humidity is 0.5 what is absolute humidity? (NOV/DEC 2014) Molal humidity (H_m) – 0.5 H_m = 1.611 x H

 $H = H_m / 1.611 = 0.5 / 1.611$ H = 0.3103kg water / kg of dry air

8. Convert 499 g of CuSO4.5H2O into moles. (NOV/DEC 2013)

Number of moles = $\frac{Mass}{Molecularweight} = \frac{499g}{159.5g/gmol} = 3.128gmol$

 State ideal gas law. (NOV/DEC 2013) For a given mass of an ideal gas the product of pressure and volume is constant at the constant temperature.

PV = nRT

P- Absolute pressure V-volume of 1 kgmol gas R- Gas constant

T – Absolute temperature

10. Define absolute humidity. (NOV/DEC 2013) (NOV/DEC 2009) It is defined as the weight of water vapor per unit weight of dry air in the mixture.

$$H = \frac{W_A}{W_B}$$

PART B

- 1. Define 'Absolute humidity, Relative humidity and Saturation humidity. (NOV/DEC 2016) (Stoichiometry by Bhatt & Vora, Pg.No.340-342)
- 2. A gas mixture containing 12% CO₂, 8% O₂ and 80% N₂ by volume leaves from the fermenter at 1.5 atm (abs) pressure and 40° C and 1 m³/hr. Calculate how many kg/hr of the gas mixture is coming out. [NOV/DEC 2014] (Stoichiometry by Bhatt & Vora, Pg.No.52-53)
- 3. A mixture of acetone vapor and nitrogen contains 15.8% acetone by volume. Calculate the relative and percent saturation of mixture at a temperature of 293 K and pressure of 101.323 kPa.

Data: Vapor pressure of acetone at 293 K = 24.638 kPa. (NOV/DEC 2016) (Class notes)

- 4. A mixture of gases has the following composition by weight $Cl_2 = 65\%$ $Br_2 = 25\%$ and $O_2 = 5\%$. Using ideal gas law calculate
- (i) Composition of the gas mixture by volume %
- (ii) Density of the gas mixture in kg/m3 at 25° C & 740 mm Hg.
- (iii) Specific gravity of the gas mixture. [NOV/DEC 2013] (Stoichiometry by Bhatt & Vora, Pg.No.51)
- 5. If the wet bulb temperature is 25° C and the dry bulb temperature is 30° C , find the following
- i) Absolute humidity
- ii) Relative humidity
- iii) Molal humidity
- iv) Humid heat
- v) Humid volume
- vi) Dew point temperature (Stoichiometry by Bhatt & Vora, Pg.No.349-351)

UNIT III – MATERIAL BALANCE PART A

1. Define adsorption process. (NOV/DEC 2016)

Adsorption involves contact of solid with either a liquid or a gaseous mixture in which a specific substance from the mixture concentrates on the solid surface. For example, (i) removal of color from solutions using activated carbon, (ii) removal of moisture from air by silica gel.

1. What is limiting and excess reactant? (NOV/DEC 2016) (APR/MAY 2015,2005)

Limiting reactant:

Limiting reactant is defined as the material that is not present in excess of that required to continue any of the other reacting materials and it is not present in the product.

Excess reactant:

A reactant which is present in excess of the stoichiometric amount in a reaction and it is always present in the product.

2. What is purge and write its necessity for a process? (APR/MAY 2015)

Purge is a stream which is discarded from the recycled stream to prevent the accumulation of certain unwanted impurities or inert materials.

It is necessary for maintaining low salt concentration in the mixed feed during recycling. It is used to control the composition of mixed feed.



3. 100 K.moles/hr of air is sent to a fermenter. What is the molar flow rate of O_2 to the fermenter? (NOV/DEC 2014)

100 k moles of air contains 79 k moles of N_2 and 21 k moles of O_2 . Molar flow rate of $O_2 = 21$ k moles/hr

4. For the reaction $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. What is theoretical requirement of O_2 per k.mol of methane? (NOV/DEC 2014)

Stoichiometric O_2 requirement =2

Theoretical requirement of $O_2 = 2$ per k mol of methane.

5. Differentiate between steady state and unsteady state. (NOV/DEC 2014,2013,2011,2005)

Steady state	Unsteady state
The condition does not change with time is known as steady state operation.	The condition changes with time is known as unsteady state operation.

6. Explain the difference between the recycle and bypass stream. (NOV/DEC 2011) **Recycle:**

It is a stream that conducts materials leaving or downstream a process back to the inlet or upstream a process is called as recycle.

Bypass:

It is a stream which skips one or more steps of process and goes directly to another process. The purpose is to control the concentration of downstream or product stream.

7. What is the need for excess air in combustion processes and how do you calculate it? (NOV/DEC 2012)

The amount of air more than the theoretical requirement is referred to as excess air.

To determine the excess air at which the combustion system will operate we have to start with the stoichiometric air-fuel ratio, known as the perfect or ideal fuel ratio, the stoichiometric combustion. During stoichiometric combustion there is a chemically correct mixing proportion between the air and the fuel. During the stoichiometric combustion process no fuel or air are left over.

10 kg of C H₄ is burnt with 10% excess air. What will be the volume of the air used for combustion if air is at 30°C and 1.3 atm pressure? (NOV/DEC 2011) Solution:

Moles of C H₄= 10/16=0.625 k moles $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

0.625 moles of methane requires 1.25 kmoles of O_2 Theoretical $O_2=1.25$ kmoles

Total O₂ = $1.25\left(1 + \frac{10}{100}\right) = 1.25(110/100) = 1.375$ Excess O₂=1.375-1.25=0.125 Excess O₂=0.125 PV=nRT R=PV/nT

$$R = \frac{1 \times 22.414}{1 \times 273.15} = 0.0820 \text{ m}^3 \text{atm/kmol.K}$$
$$V = nRT/P = \frac{0.125 \times 0.0820 \times 303}{1.3} \qquad kmol \times \frac{m^3 atm}{kmol.K} \times K \times \frac{1}{atm}$$
$$V = 2.389 \text{ m}^3$$

Volume of air = 2.389 m^3

9. Define yield and excess component in chemical reaction. (NOV/DEC 2010) **Yield:**

yield is defined as the ratio of the moles of reactants converted to main product to its moles of reactants taking part in the reaction.

Excess component:

A component which is present in excess of the stoichiometric amount in a reaction and it is always present in the product.

- 10. Name any four separation processes. (APR/MAY 2010)
 - (i) Absorption
 - (ii) Distillation
 - (iii) Extraction
 - (iv) Crystallization
- 11. Give the recycle and bypass operations in chemical industries with one example. (NOV/DEC 2010)(APR/MAY 2010)

Recycle operations in chemical industries:

Recycle process improves the performance of equipment as in the case of absorption of sulphur trioxide using sulphuric acid rather than water, as the solubility is low in pure water.



Bypass operations in chemical industries:

Bypassing of a fluid stream is dividing it into two streams, and is often used in industries to have a closer control in operation. This is done if there is a sudden change in the property of a fluid stream likes excessive heating (or cooling) as it passes through a preheater (cooler) before entering another unit.



12. Define degrees of freedom. (NOV/DEC 2009,2006)

Degree of freedom is defined as the number of independent variables required to define system completely.

Phase rule: F = C - P + 2

- F Degree of freedom
- C Number of component
- P Number of phases
- 13. What is the purpose of recycle and bypass? (NOV/DEC 2009)

Purpose of recycle:

- (i) To improve the conversion whenever the conversion is low and to have energy economy in operations
- (ii) To improve the performance of equipment.
- (iii) To improve the selectivity of a product.
- (iv) To control the operating variable in a reaction like pressure, temperature.
- (v) To minimize waste generation.

Purpose of bypass:

The purpose of bypass is to control the concentration of the downstream (product stream)

14. What is recycle? Explain. (NOV/DEC 2008, 2007,2005)

Recycle:

A part of the main product stream or the intermediate product stream comprising both reactants and products or the intermediate product is sent back along with feed to the system or somewhere in the middle of the system. Such stream is called recycle stream.

15. What is bypass? Explain. (NOV/DEC 2008, 2007,2005)

Bypass:

Bypassing of a fluid stream is dividing it into two streams, and is often used in industries to have a closer control in operation. This is done if there is a sudden change in the property of a fluid stream likes excessive heating (or cooling) as it passes through a preheater (cooler) before entering another unit. In such cases this conditional stream is mixed with a portion stream at its original condition and then used in the process. This is called bypassing operation.

16. Explain weight percent. (NOV/DEC 2008)

Weight percent:

It is defined as the ratio of weight of a particular component to the total weight of the system in every 100 part.

Weight % of A =
$$\frac{W_A}{W} \times 100$$

17. Explain mole percent. (NOV/DEC 2008) Mole percent:

Mole % of A = mole fraction of A x 100

Mole fraction of A =
$$\frac{\frac{W_A}{M_A}}{\frac{W_A}{M_A} + \frac{W_B}{M_B}}$$

- 18. What is steady state? Explain. (NOV/DEC 2006) The condition does not change with time is known as steady state operation.
- Classify various types of Unit operations. (NOV/DEC 2005) It deals mainly with the transfer and change of energy & transfer and change of materials primarily by physical means but also by physical – chemicals means.

Eg: Filtration, Drying, Distillation etc

20. What are the objectives of Unit Processes? (NOV/DEC 2005) It deals mainly with process involving chemical reactions. Eg: Nitration, Chlorination

21. Distinguish between evaporation and drying. (APR/MAY 2005)

Evaporation	Drying
Evaporation is defined as the process of removal of water from a substance.	Drying is defined as the process of removal of moisture from a substance.

22. Explain Dalton's law. (NOV/DEC 2005)

Daltons Law states that the total pressure of a mixture of gases is equal to the sum of the partial pressures of the constituent gases. The partial pressure is the pressure each gas would exert if it alone occupied the volume of the mixture.

Daltons Law for moist air can be expressed as $p = p_a + p_w$, where p = total pressure of air (Pa, N/m²), $p_a = partial$ pressure dry air (Pa, N/m²), $p_w = partial$ pressure water vapor (Pa, N/m²)

23. Define the following for a binary mixture. (a) mol fraction (b) vol%

- a. Mole Fraction is defined as the ratio moles of one component to the total number of moles.
- b. Volume % = $\frac{\text{Volume of one component x 100}}{\text{Total Volume}}$

Molecular Weight	Equivalent Weight
It is defined as the ratio of the given weight of the substance to the no. of gram moles of the substance.	It is defined as the ratio of the given weight of the substance to the no. of gram equivalents of the substance.
Molecular Weight = Equ	ivalent Weight x Valency

24. Distinguish between molecular weight and equivalent wt?

25. A solution of caustic soda contains 30% NaOH (by Weight). The density of the solution is 1.196 gm/cc. Find the molarity and normality of the solution. Basis : 100 g of NaOH solution

Density = $1.196 \text{ g/cc} = 1.196/1000*10^6 = 1196 \text{ kg/m}^3$

Component	Weight (g)	Mol.Wt	g moles
NaOH	30	40	0.75
H ₂ O	70	18	3.89

Volume of the solution = Mass / Density = $100*10^{-3}/1196$

 $= 0.08 * 10^{-3} m^3 = 0.08 lit$

For NaOH Equivalent weight = Molecular weight

- a) Molarity = g moles of solute / one litre of the solution = 0.75/0.08 = 9.375M
- b) Normality = g equivalents of the solute / one litre of the soln. =0.75/0.08 = 9.375N

26. Define selectivity

The ratio of amount of limiting reactant that reacts to give the desired product to the amount that reacts to give undesirable products.

27. Determine the weight of water removed while drying 1000kg of wet cake from 56% to 7%.

<u>Basis</u>: 1000kg of wet cake Let x be the amount of H₂O removed H₂O balance 1000 * 56/100 = x + (1000-x)* 7/100560 = x + 70 - 0.07xX= 490/0.93 = 526.88 Kg of H₂O

28. Define conversion.

Conversion is defined as the ratio of the reacting amount of a component to its initial amount. It is expressed as mole %, mass % (or) volume %.

29. Define reflux ratio.

Reflux ratio is defined as the ratio of refluxed quantity to the actual product.

Re flux ratio =
$$\frac{\text{Re fluxed quantity}}{Actual product} = \frac{R}{D}$$

30. Define crystallization.

Crystallization is a process in which the solid particles are formed from a homogeneous phase.

During crystallization, the crystals form when a saturated solution gets cooled. The solution left behind after the separation of crystals is known as mother liquor or saturated solution. The mixture of crystals and mother liquor is known as magma.

PART B

1. Define Absorption, Distillation and Extraction operations.(NOV/DEC 2016) (Stoichiometry by Bhatt & Vora, Pg.No.321,333,325)

(ii) 1000 Kg/hr of solution containing 20% methanol is continuously fed to a distillation column. Distillate is found to contain 98% methanol and waste solution from the column contains 1% methanol. Calculate: (1) Mass flow rate of Distillate and Bottom product.

- (2) The percent loss of methanol. . (NOV/DEC 2016) (Class notes)
- 2. (i) Define yield and selectivity. .(NOV/DEC 2016)(Stoichiometry by Bhatt & Vora, Pg.No.112-114)

(ii) Pure CO₂ is produced by treating limestone containing CaCO₃, MgCO₃ and Inerts, with sulphuric acid. The residue from the process contains Ca SO₄ – 8.56%, MgSO₄-5.23%, H₂SO₄-1.05%, Inerts-0.53%, CO₂-0.12% and H₂O – 84.51%. Calculate the amount of CaCO₃, MgCO₃ and Inerts in limestone. (NOV/DEC 2016) (Class notes)

- 3. The waste acid from nitrating process contains 23% HNO₃, 57% H₂SO₄ and 20% H₂O. This has to be concentrated to contain 27% HNO₃ and 60% H₂SO₄ by the addition of 93% conc. H₂SO₄ and 90% conc. HNO₃. Calculate the weight of waste and conc. acid that must be combined to obtain 1000 Kg of the desired mixture. [NOV/DEC 2013] (Stoichiometry by Bhatt & Vora, Pg.No.70-71)
- 4. 1000 kg of Na₂CO₃ solution containing 25% Na₂CO₃ is subjected to evaporative cooling. During its process 15% of H₂O present in the solution is evaporated. From the concentrated solution Na₂CO₃10.H₂O crystallizes out. Calculate how much crystals would be produced if the solubility of Na₂CO₃ is 21.5 g per 100 g of H₂O. [NOV/DEC 2011] (Stoichiometry by Bhatt & Vora, Pg.No.333)
- A solution containing 53.8 g MgSO₄/100g of water is cooled from 353 K to 323 K. during the process, 6% of water evaporates. How many kg of MgSO₄.7H₂O crystals obtained per 100 kg of the original solution? at 323 K the solution contains only 0.3 mass fraction of MgSO₄. [NOV/DEC 2015] (Stoichiometry by Bhatt & Vora, Pg.No.334-335)
- 6. It is required to make 1000 kg mixed acid containing 60% H₂SO₄ , 32% HNO₃ and 8% water by blending
 - (i) The spent acid containing 11.3% HNO₃, 44.4% H₂SO₄ and 44.3% H₂O
 - (ii) Aqueous 90% HNO₃, and

(iii) Aqueous 98% H₂SO₄. All percentages are by mass. Calculate the quantities of each of three acids required for blending. (Stoihiometry by Bhatt & Vora, Pg.No.70-71)

PART C

- 1. A tank contains 100 litres of salt solution in which 5 kg of salt is dissolved. Water flows into the tank at the rate of 5 litres/min and salt solution leaves the tank from the top at the same rate. Due to complete mixing, the concentration of salt in the tank is uniform at all times. Find the amount of salt in the tank at the end of 50 min. Take the density of the salt solution as 1 kg/litre. (NOV/DEC 2106)(Class notes)
- 2. Pure sulphur is burnt in a burner at the rate of 0.3 kg/s. fresh dry air is supplied at 30°C and 100 kPa. The gases from the burner contain 16.5%SO₂, 3% O₂ and rest N₂ on SO₃ free volume basis. The gases leave the burner at 800°C and 101.325 kPa. Calculate the
- (i) Fraction of sulphur burnt into SO₃
- (ii) The percentage excess air over the amount required to oxidize sulphur to SO₂
- (iii) The volume of dry air in m^3/s
- (iv) The volume of burner gases in m³/s. [NOV/DEC 2015] (Stoichiometry by Bhatt & Vora, Pg.No.125-126)
- 3. Fresh juice contains 15% solids and 85% water by weight and is to be concentrated to contain 40% solids by weight. In order to overcome these problems parts of the fresh juice bypass the evaporator. Calculate
 - (i) The fraction of juice that bypass the evaporator.
 - (ii) The concentrated juice produced (containing 40% solids) per 100 kg of fresh juice fed to the process. [NOV/DEC 2013] (Stoichiometry by Bhatt & Vora, Pg.No.142)



Bypass Juice, 15% solids

UNIT IV – ENERGY BALANCE PART A

- What is conversion? (NOV/DEC 2016) Conversion is defined as the ratio of the reacting amount of a component to its initial amount. The amounts can be expressed as mole%, mass % or volume %. The conversion is also expressed as mole%, mass % or volume %.
- 2. State Hess's law. (NOV/DEC 2016) The heat evolved or absorbed in a chemical reaction is the same whether the reaction takes place in single step or in a series of step, this is known as Hess's law.
- 3. Brief the difference between sensible and latent heat with an example.(APR/MAY 2015,2011)(NOV/DEC 2009)

Sensible heat:

The heat which can be measured by a measuring device. It occurs within the same phase.

Latent heat:

The heat which cannot be measured by a measuring device and which accompanies the phase change.

4. Write the energy balance relation for a chemical reaction in an open system. .(APR/MAY 2015)

Energy Balances on Open Systems

First law of thermodynamics

$$\oint dQ = \oint dW$$

$$Q = UTotal + WTotal$$

$$U_{Total} = Q + WTotal$$

 $\Delta u + \Delta E kinetic + \Delta E potential = Q - (W shaft + W flow)$

 $\Delta H = \Delta u + W flow$

$$(\Delta u + W flow) + \Delta E kinetic + \Delta E potential = Q - (W shaft)$$

 $\Delta H + \Delta E kinetic + \Delta E potential = Q - W shaft$

5. If C_p of a gas is $C_p = a + bT + cT^2$, T in K what will be the heat required to heat one mole from T₁ to T₂. (NOV/DEC 2014)

Solution:

$$\Delta H = \int nC_{P}dT$$

$$= \int_{T_{1}}^{T_{2}} 1C_{P}dT$$

$$= \int_{T_{1}}^{T_{2}} (a + bT + cT^{2})dT$$

$$= \left[aT + b\frac{T^{2}}{2} + c\frac{T^{3}}{3}\right]_{T_{1}}^{T_{2}}$$

$$\Delta H = a(T_{2} - T_{1}) + \frac{b}{2}(T_{2}^{2} - T_{1}^{2}) + \frac{c}{3}(T_{2}^{3} - T_{1}^{3})$$

6. For a reaction at $aA + bB \rightarrow cC + dD$ using heat of formation data, what will be ΔH_R° ? (NOV/DEC 2014)

Solution:

$$\Delta H_{R}^{\circ} = \sum_{\text{Products}} n\Delta H_{f}^{\circ} - \sum_{\text{Re} \, a \, c \, \tan ts} n\Delta H_{f}^{\circ}$$
$$\Delta H_{R}^{\circ} = (d\Delta H_{fD}^{\circ} + c\Delta H_{fc}^{\circ}) - (a\Delta H_{fA}^{\circ} + b\Delta H_{fB}^{\circ})$$

7. State the first law of thermodynamics. (NOV/DEC 2012)

The 1st Law of Thermodynamics tells us that energy is neither created nor destroyed, thus the energy of the universe is a constant. However, energy can certainly be transferred from one part of the universe to another Thus power generation processes and energy sources actually involve conversion of energy from one form to another, rather than creation of energy from nothing.

The energy transfer between different systems can be expressed as $E_1 = E_2$, where

 E_1 = initial energy & E_2 = final energy

8. Define entropy. (NOV/DEC 2012)

Entropy is used to define the unavailable energy in a system. Entropy defines the relative ability of one system to act to another. As things moves toward a lower energy level, where one is less able to act upon the surroundings, the entropy is said to increase. The second law is concerned with entropy (S). Entropy is produced by all processes and associated with the entropy production is the loss of ability to do work. The second law says that the entropy of the universe increases.

 State and explain Raoult's law.(APR/MAY 2011) (NOV/DEC 2007,2005) Raoult's law states that the vapour pressure of the solvent in a solution is directly proportional to the mole fraction of the solvent.

10. Calculate the enthalpy of sublimation of iodine from the following reactions and the data

 $\begin{array}{ll} H_2(g) + I_2(S) \rightarrow 2HI(g) & \Delta H = 57.9 \text{ KJ / mol} \\ H_2(g) + I_2(g) \rightarrow 2HI(g) & \Delta H = -9.2 \text{ KJ / mol} \\ \text{Solution:} \\ \text{Equation 1 - equation 2 gives the desired reaction} \end{array}$ (NOV/DEC 2011)

$$I_{2(s)} \to I_{2(g)}$$
 [57.9 - (-9.2)]
 $\Delta \mathbf{H} = 67.1 \text{ kJ}$

11. What is Trouton's rule? (NOV/DEC 2011)

The ratio of molal heat vaporization λ_b of a substance at its normal boiling point to the absolute temperature T_b is constant.

$$K = \frac{\lambda_b}{T_b}$$

Where k is termed as Trouton's ratio. For many substances this ratio is equal to approximately 21.

12. Define the terms: sensible heat and latent heat. (APR/MAY 2010)(NOV/DEC 2010,2008,2006,2005)

Sensible heat:

The heat which can be measured by a measuring device. It occurs within the same phase.

Latent heat:

The heat which cannot be measured by a measuring device and which accompanies the phase change.

13. What is the relation between vapor pressure and boiling point of liquids? (APR/MAY 2010)(NOV/DEC 2009)

Vapour pressure: it is defined as the absolute pressure at which the liquid and its vapour are in equilibrium at a given temperature. Boiling point of liquids:

14. What is a state function? Give examples. (NOV/DEC 2010) It is a property which is independent of the path followed by the system. It is otherwise known as point function.

(eg) temperature, pressure, volume.

- 15. What is vapor pressure? (NOV/DEC 2009) Vapour pressure is defined as the absolute pressure at which the liquid and its vapour are in equilibrium at a given temperature.
- 16. State the second law of thermodynamics. (NOV/DEC 2008) The 2nd law is needed to determine the direction of processes. The second law is concerned with entropy, which is a measure of disorder. The second law says that the entropy of the universe increases. The second law is a generalization of experiments dealing with entropy--it is that the dS of the system plus the dS of the surroundings is equal to or greater than 0. Entropy is not conserved like energy.
- 17. Define specific heat and molar heat capacity. (NOV/DEC 2007)
 Specific heat: Specific heat of a substance is the ratio of the heat capacity of a particular substance to that of water.
 Molar heat capacity: Heat energy required to raise the temperature of 1 mole of substance by 1°C/1K.

18. Write down the equation for the conservation of momentum. (APR/MAY 2005) The general momentum equation is also called the equation of motion or the Navier-Stoke's equation; in addition the equation of continuity is frequently used in conjunction with the momentum equation.

(Rate of momentum accumulation) = (rate of momentum in) - (rate of momentum out) + (sum of forces acting on the system)

19. Define: heat of formation and heat of reaction. .(APR/MAY 2005)

Heat of formation: The thermal change involved in the formation of 1 mole of a substance from the elements is called the heat of formation of a substance. (ΔH_f)

Heat of reaction: It is defined as the enthalpy of products minus the enthalpy of reactants. (ΔH_R)

PART B

 (i) A liquid ethanol fermentation medium at 45°C is pumped at the rate of 1000 kg/hr through enters at 75°C and leaves at 90°C, the average heat capacity of the medium and water is 3.986 and 5.21 kJ/kg K. respectively the medium stream and hot water stream are separated by a metal surface through which heat is transferred and do not physically with each other. Make the complete heat balance of the system and calculate the hot water flow and the amount of heat added to the fermentation medium assuming there is no heat loss in the system. [NOV/DEC 2013] (Stoichiometry by Bhatt & Vora, Pg.No.)

(ii) Heat capacity of acetic acid is given by $Cp = 155.48 - 326.595 \times 10^{-3}T + 744.199 \times 10^{-6} T^2$ based on this equation, calculate the mean capacity for acetic acid for temperature range of 25°C to 50°C [NOV/DEC 2013] (Refer class notes)

- 2. Explain the various thermodynamic processes like constant volume, constant pressure, isothermal & adiabatic process. (Stoichiometry by Bhatt &Vora, Pg.No.265-271)
- 3. The heat capacity of CO_2 is given by the following relation
 - $Cp = 26.540 + 42.454 \times 10^{-3}T 14.298 \times 10^{-6} T^2$ where Cp KJ/Kmol K and T is in Kelvin.
 - (i) How much heat is required to heat 1 kg of CO_2 from 300 K to 1000K?
 - (ii) Obtain the relation expressing the heat apacity in kcal/kmol°C and temperature in °C
 - (iii) Obtain the relationship giving heat capacity in Btu/lb mol °F and temperature in °F [NOV/DEC 2015] (Stoichiometry by Bhatt & Vora, Pg.No.184-193)
- 4. Estimate the heat of vapourization of methyl chloride at 30°C from the Clapeyron equation assuming ideal behavior for the vapour phase. The vapour pressure (kPa) is given by

 $\ln P^{s} = 14.2410 - \frac{2137.72}{T - 26.72} \quad \text{Where T is in K. [NOV/DEC 2015]}$

(Stoichiometry by Bhatt & Vora, Pg.No.206-207)

PART C

 (i) Define sensible heat and latent heat.(NOV/DEC 2016)](Stoichiometry by Bhatt & Vora, Pg.No.194-195& 205-206)

(ii) Calculate the standard heat of reaction of the following reaction at 298 K and 101.32 k pascal for 4 Kg mol of NH_3 (NOV/DEC 2016)(Class notes)

$4 \text{ NH}_3 (g) + 5 \text{ C}$	$D_2(g) \rightarrow 4 \text{ NO}(g) + 6 \text{ H}_2\text{O}(g)$
Compound	<u>ΔH_f (kJ/ mol at 298 K</u>
NH ₃ (g)	- 45.94
NO (g)	90.374
$H_2O(g)$	- 241.82
	$4 \text{ NH}_{3} (g) + 5 \text{ C}$ $\frac{\text{Compound}}{\text{NH}_{3} (g)}$ $\text{NO } (g)$ $\text{H}_{2}\text{O} (g)$

2. (i) How is calculated standard heat of reaction from heat of formation and heat of combustion data? (NOV/DEC 2016) (Stoichiometry by Bhatt & Vora, Pg.No.260-262)
(ii) 100 kg/hr of methanol liquid at a temperature of 303 K is obtained by removing heat from saturated methanol vapor. Find out the amount of heat to be removed. Data: Boiling point of methanol = 337.8 K
Latent heat of condensation of methanol = 1101.7 KJ/kg
Specific heat of methanol = 2.7235 (KJ/kg.K) (NOV/DEC 2016) (Class notes)

UNIT – V CHEMICAL REACTION

State kopp's law.
 Kopp's law: The heat capacity of a solid compound is approximately equal to the sum of the heat capacities of the constituent elements.

2. Define adiabatic reaction temperature.

Adiabatic reaction temperature is the temperature attained by reaction products, if the reaction proceeds without loss or gain of heat and if all the products of the reaction remain together in a single mass or stream of materials.

- 3. Explain theoretical flame temperature. The temperature attained when a fuel is burnt in air or oxygen without loss or gain of heat is called the theoretical flame temperature.
- 4. Define heat of mixing.

When two solutions are mixed, the heat evolved or absorbed during the mixing process is known as heat of mixing.

5. What is state function and path function? **State function**: It is a property which is independent of the path followed by the system. It is otherwise known as point function.

(eg) Temperature, Pressure, Volume.

Path function: it is a property which is dependent of the path followed by the system. (eg) Heat, Work.

6. Write notes on extensive property and intensive property.
Extensive property: It is a state of system, which depends on the mass under consideration. (eg) Volume, Enthalpy.
Intensive property: This state of a system is independent of mass. An example of this property.

Intensive property: This state of a system is independent of mass. An example of this property is temperature, density, viscosity, entropy, internal energy.

7. Distinguish between heat and temperature?

Heat	Temperature
1. It is a form of energy in transit	1. It is a property used to measure
(always flow).	heat energy.
2. Heat is a path function.	2. Temperature is a state function.
3. Unit of heat is Joule.	3. Unit of temperature is K $/^{\circ}$ C /
4. It is extensive property.	°F / °R
	4. It is intensive property.

8. What is a system and explain the types of system?

System refers to a substance or group of substances under consideration, (eg) storage tank, water in a tank, etc.

Types of system:

- (i) Closed system or non flow system
- (ii) Open system or flow system
- 9. Define latent heat of sublimation

The amount of heat required to convert 1 kg or kmol of solid substance into gas phase. Latent heat of sublimation is denoted by the symbol (λ_s). The unit of λ_s is kJ/kg (or) kJ/kmol.

10. Define latent heat of fusion.

The amount of heat required to convert 1 kg or kmole of solid substance into liquid phase. Latent heat of fusion is denoted by the symbol (λ_F). The unit of λ_F is kJ/kg (or) kJ/kmol.

11. Define vapourization.

It is defined as the heat required to vapourize 1 kg or 1 kmol of liquid substance. Latent heat of sublimation is denoted by the symbol (λ_V). The unit of λ_V is kJ/kg (or) kJ/kmol.

12. Define standard heat of combustion.

The standard heat of combustion is that resulting from the combustion of a substance, in the state that is normal at 298 K and atmospheric pressure, with the combustion beginning and ending at 298 K.

13. Define state.

The given set of properties of material at a given time. The state of a system does not depend on the shape or configuration of the system but only on its intensive properties such as temp, pressure and composition.

PART B

1. (i) Explain the concept of heat capacity and how it is being calculated for various substances. (Stoichiometry by Bhatt & Vora, Pg.No.181-184)

(ii) Show that $(C_p - C_v) = R$ for an ideal gas. [NOV/DEC 2010] (Stoichiometry by Bhatt & Vora, Pg.No.181-182)

2. Calculate the amount of heat given off when 1 m3 of air at standard conditions cools from 500°C to -100°C at constant pressure.

 $Cp_{air} = 6.386 + 1.763 \times 10^{-3}T - 0.2656 \times 10^{-6} T^2$ Kcal/Kmol K and T is in Kelvin. [NOV/DEC 2013] (Stoichiometry by Bhatt & Vora, Pg.No.193-194) 3. The Orsat analysis of the flue gases from a boiler house chimney gives CO2:11.4%, O2:4.2% and N2:84.4% (mole%). Assuming that complete combustion has taken place, (a) Calculate the % excess air, and (b) find the C:H ratio in the fuel. (Stoichiometry by Bhatt & Vora, Pg.No.416-417)