

R3910

Scheme of Valuation/Answer Key

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

THIRD SEMESTER B.TECH DEGREE EXAMINATION, DECEMBER 2018

Course Code: CH201

Course Name: CHEMICAL PROCESS CALCULATIONS

Max. Marks: 100

Duration: 3 Hours

PART A

Answer any two full questions, each carries 15 marks.

Marks

- 1 a) Convert Btu/(ft hr⁰F) to Kcal/(mhr⁰C)
1 Btu= 252 Cal, 1ft=0.3048 m $\Delta^0F=1.8\Delta^0C$ (1)
Substitute and find the value (1)
- b) Basis- 100 gm of solution (1)
Molarity = no. of moles of KOH/ volume of solution in litres (1)
Weight of KOH - 30.2 gm
No. of moles of KOH= 30.2/MW of KOH= 30.2/56
Molarity= (30.2/56)/volume of solution= 7.0
Volume of solution=0.5393/7.0= 0.077 litres (1)
Density= mass/volume= 100/0.077= 1298 g/litres= 1298 kg/m³ (1)
- c)
$$API = \frac{141.5}{sp. gr\ 228.8K} - 131.5$$
 (1)
Find sp.gravity by substitution (1)
- (d) Basis: 100 moles of the mixture at std conditions (1)

Name	No. of moles	MW	Weight (gm)	Weight %
CH ₄	30	16	80	38.46
C ₂ H ₄	20	28	560	26.92
N ₂	40	28	1120	53.84
O ₂	10	32	320	15.38
		Total	2080	100

ii) average MW = 2080/100 = 20.80 (1)

iii) density = Mass/ volume

$$= 20.80/22.4=0.9286 \text{ gm/lit} \quad (2)$$

- 2 a) Unit operations- consists of physical operations eg:- evaporation, distillation etc (1)
 Unit processes- involves chemical reactions eg:- saponification, hydrolysis, etc (1)
- b) Basis: 100 gm of solution (1)
 Alcohol – 50 gm, Water - 50 gm
 No. of moles of alcohol= $50/46=1.087$ moles (1)
 Volume of solution= $100/0.914 =109.409$ cc = 0.1094 litres (1)
 i) Molarity = $1.087/0.1094 = 9.936$ mol/L (1)
 ii) Molality = $1.087*1000/(50) = 21.74$ mol/kg water
 iii) Volume of water = $50/0.998 = 50.1$ cc (1)
 Volume of alcohol = $50/0.780 = 64.10$ cc
 Volume % alcohol = $64.10/109.409= 58.6$ % (1)
- c) Basis : 100 moles of the mixture (1)
 Let x - no of moles of oxygen present, y - no. of moles of SO₂ present
 $x + y = 100$ (1)
 $32x + 64y = 4480$ (1)
 Solve for x and y → composition in mole % **ans** (1)
 Convert to weight % **ans** (2)
 Partial pressure of oxygen = mole fraction of oxygen*total pressure
 = $(x/100)*200$ kPa **ans** (1)
- 3 a) Basis: 100 gm of solution (1)
 Weight of H₂SO₄ present = 2.45, no of equivalentents = $2.45/49 = 0.05$ (1)
 Density = 1.011 g/cc
 Volume of solution = $100/1.011= 98.91$ cc= 0.09891 litres (1)
 Normality = $0.05/0.09891= 0.5055$ N (1)
- b) $\frac{Btu}{hr.ft^2.o_F}$ to $\frac{cal}{min(cm^2)o_C}$ (2)
 $1 Btu = 252 cal$
 $1 hr = 60 min$
 $1 ft = 30.48 cm$
 $1\Delta^0F = 1.8\Delta^0C$
 $\frac{lb}{hr.ft^2}$ to $\frac{g}{min(cm^2)}$ (2)
 $1 lb = 453.4 gm$
 Substitute and find the equation (2)

- c) Compressibility factor ($Z = PV/RT$), Valid points of explanation ---- deviation (2)
 from ideality
 construction of compressibility factor chart (2)
 application (1)

PART B

Answer any two full questions, each carries 15 marks.

- 4 a) State the Clausius-Clapeyron equation (1)
 Derivation of Clausius-Clapeyron equation (2)
 Assumptions (listing 3 assumptions) (1)
- b) Relative humidity = partial pressure/vapour pressure (1)
 Partial pressure = $0.8 \times 17.5 = 14$ mm Hg
 Percent humidity = Absolute humidity/ saturation humidity
 Absolute humidity = $14/(750-14) = 0.01902$ (1)
 Saturation humidity = $17.5/(750-17.5) = 0.02389$ (1)
 Percent humidity = 79.61 % (1)
- c) Basis : 100 moles/hr of feed (1)
 D- moles of distillate , W- moles/hr of bottom Product
 Write overall balance, $100 = D+W$ (1)
 Determine composition of feed, distillate and bottom product in mole percentage (3)
 $X_f = (40/78)/(40/78+60/92)$
 $X_d = (97/78)/(97/78+3/92)$
 $X_w = (5/78)/(5/78+95/92)$
 Benzene balance $\rightarrow 100 \times X_f = D \times X_d + W \times X_w$ (1)
 Solve for D and W (1)
- 5 a) $101 = x \times 156 + (1-x) \times 63$ (1)
 Solve for x - composition of benzene in liquid phase, (1)
 (1-x) - Toluene composition (1/2)
 $y = x \times 156/101$ - composition of benzene in vapour phase, (1)
 (1-y) - toluene composition (1/2)
- b) Definition of WBT (1)
 Adiabatic Saturation Temperature (1)
 Dew point (1)
- c) Basis : 100 kg of 30 % Na_2SO_4 solution fed (1)
 W_1 - weight of crystals formed

W_2 - weight of mother liquor

$$\text{Total balance, } 100 = W_1 + W_2 \quad (1)$$

$$\text{Na}_2\text{SO}_4 \text{ balance, } 100 \cdot 0.3 = (W_1 \cdot 142/342) + (W_2 \cdot 0.1) \quad (2)$$

$$\text{Solve for } W_1 \text{ (ans)} \quad (1)$$

(d) **Bypass:** Diagram + Explanation (1.5)

Recycle: Diagram + Explanation (1.5)

6 a) Use psychrometric chart, schematically represent and find

$$\text{Absolute humidity (Y')} = 0.035 \text{ kg/kg dry air} \quad (2)$$

$$\text{Molal humidity } Y = Y' \cdot 29/18 = 0.0564 \text{ kmol/kmol dry air} \quad (2)$$

$$\text{Percent saturation PS} = 30\% \quad (1)$$

$$\text{Wet Bulb Temperature} = 310.5 \text{ K} \quad (1)$$

$$\text{Humid volume } V_H = 0.98 \text{ m}^3/\text{kg} \quad (1)$$

b) Basis: 100 kg/h solution fed (1)

NaCl present- 10 kg (1)

NaOH- 10kg

Water- 80 kg

W_1 - Crystals formed, kg

W_2 -concentrated liquor, kg

W_3 - water evaporated

$$100 = W_1 + W_2 + W_3 \quad (1)$$

$$\text{NaOH balance, } 10 = W_2 \cdot 0.5 \quad (1)$$

$$\text{NaCl balance, } 10 = W_1 + W_2 \cdot 0.02 \quad (1)$$

Determine W_1 and W_2 (1)

c) Key component definition (1)

Eg., ash in coal, pulp in paper etc (1)

PART C

Answer any two full questions, each carries 20 marks.

7 a) Carbon burnt= $6/12 = 0.5$ moles (1)

$$\text{O}_2 \text{ fed} = 18/32 = 0.5625 \text{ moles} \quad (1)$$

Limiting reactant – carbon (1)

$$\text{Carbon reacted} = 16.5 \cdot 12/44 + 2.8 \cdot 12/28 = 4.5 + 1.2 = 5.7 \text{ gm} \quad (2)$$

$$\text{Conversion} = 5.7/6 \cdot 100 = 95\% \quad (1)$$

b) Proximate analysis: valid points and Method of analysis (2)

Ultimate analysis: valid points and Method of analysis (2)

c) Basis: 1 mole of CO burned (1)

Reactants

CO = 1 mole at 1000 K

O₂ = 0.5*1.9 = 0.95 moles at 800K (1)

N₂ = 0.95*79/21 = 3.574 moles at 800 K (1)

Products

CO₂ - 1mole (1)

O₂ - 0.45 moles (1)

N₂ - 3.574 moles (1)

$\Delta H = \Delta H_1 + \Delta H_{298}^0 + \Delta H_2$ (1)

ΔH_1 = heat of reactants

$$= 1*29.38(298-1000) + 0.95*33.13(298-800) + 3.574*31.43(298-800) \quad (1)$$

ΔH_2 = heat of products

$$= 1*49.91(1250-298) + 0.45*33.13(1250-298) + 3.574*31.43*(1250-298) \quad (1)$$

$\Delta H_{298}^0 = -282.99$ kJ/mol

Find the value of ΔH ---- heat evolved in the reaction (1)

8 a) Basis: 100 moles of flue gas (1)

CO₂- 8.7 moles, CO- 1.0 mole, O₂- 2.0 moles and N₂-88.3 moles.

Taking carbon balance, Carbon present in the flue gas = 8.7+1.0 = 9.7 moles

CH₄ present in fuel- 9.7 moles

Nitrogen balance -> N₂ present in fuel+ N₂ supplied = N₂ present in flue gas

Oxygen balance → O₂ present in flue gas = 8.7+0.5+2.0 = 11.2 moles (1)

O₂ supplied = 11.2+ O₂ used for H₂O = 11.2+9.7 = 20.9 moles (1)

N₂ supplied = 20.9*79/21 = 78.62 moles (1)

N₂ present in fuel = 88.3-78.62 = 9.68 moles (1)

Composition of fuel

CH₄ - 9.7 moles = 50% N₂ - 9.68 moles = 50% (1)

O₂ required = 9.7*2 = 19.4 moles

O₂ supplied = 20.9 moles

% excess = (20.9-19.4)/19.4 = 7.73% (1)

b) Heat of vaporization calculation (3)

i) Clapeyron equation

- ii) Watson equation
- iii) Kistyakowsky equation--- give equations with description
- (c) Basis: 1 mole of CO burned (1)
- Reactants at 400 K (1)
- CO = 1 mole
- O₂ = 0.5*3 = 1.5 moles
- N₂ = 1.5*79/21 = 5.64 moles
- Products at 600 K (2)
- CO₂ = 1 mole
- O₂ = 1 mole
- N₂ = 5.64 moles
- $\Delta H = \Delta H_1 + \Delta H^{0}_{298} + \Delta H_2$ (1)
- $\Delta H_1 = \text{heat of reactants} = (1 \times 29.10 + 1.5 \times 29.70 + 5.64 \times 29.10)(298 - 400)$ (2)
- $\Delta H_2 = \text{heat of products} = (1 \times 41.45 + 1 \times 29.70 + 5.64 \times 29.10)(600 - 298)$ (2)
- $\Delta H^{0}_{298} = -282.99 \text{ kJ/mol}$
- Find the value of ΔH ---- heat evolved in the reaction (1)
- 9 a) Basis: 100 kg of fuel burned (2)
- H = 5.0 kg, S = 4.0 kg, C = 65 kg = 65/12 = 5.412 moles, O = 10 kg and inerts = 16 kg
- CO₂ formed = 5.412*0.8 moles = 4.33 moles (1)
- CO formed = 5.412*0.15 = 0.8118 moles (1)
- SO₂ formed = 4/32 moles = 0.125 moles (1)
- H₂O formed = 5/2 = 2.5 moles (1)
- Theoretical Oxygen required = 5.412 + 0.125 + 1.25 - 0.3125 = 6.4745
- Oxygen supplied = 1.2*6.4745 = 7.7694 moles (1)
- Products
- CO₂ = 4.33 moles - 11.2%
- CO = 0.8118 moles - 2.1% (3)
- SO₂ = 0.125 moles - 0.32%
- H₂O = 2.5 moles - 6.47%
- Oxygen = 7.7694 - (4.33 + 0.8118/2 + 1.25 + 0.125) = 1.6585 moles - 4.29%
- N₂ = 7.7694*79/21 = 29.23 moles - 75.6%
- Total = 38.6553 moles
- b) Basis: 1 mole of CO burned (1)

Reactants at 373 K (1)

CO= 1 mole

O₂=0.5*2=1.0 moles

N₂=1.0*79/21=3.76 moles

Products at T (2)

CO₂- 1mole

O₂=0.5 moles

N₂=3.76 moles

$$\Delta H = \Delta H_1 + \Delta H^{0}_{298} + \Delta H_2 \text{-----(1)} \quad (1)$$

Let T- be the theoretical flame temperature (1)

$$\Delta H_1 = \text{heat of reactants} = (1 * 29.23 + 1.0 * 34.83 + 3.76 * 33.03)(298 - 373) \quad (2)$$

$$\Delta H_2 = \text{heat of products} = (1 * 53.59 + 0.5 * 34.83 + 3.76 * 33.03)(T - 298)$$

$$\Delta H^{0}_{298} = -282.99 \text{ kJ/mol}$$

$\Delta H = 0$ since the process is adiabatic

Solve for T = 1820 K (2)

