Exam Date & Time: 12-Dec-2023 (09:30 AM - 12:30 PM)

MANIPAL ACADEMY OF HIGHER EDUCATION

3RDSEMESTER B.TECH END SEMESTER EXAMINATIONS, NOV-DEC 2023

CHEMICAL PROCESS CALCULATIONS [CHE 2122]

Marks: 50 **Duration: 180 mins.**

A

Answer all the questions.

Instructions to Candidates: Answer ALL questions Missing data may be suitably assumed

1) The heat transfer coefficient for a stream to another is given by

A) $$h = 16.6\ C_p\ G^{0.8}/D^{0.2}$$

Where, h = Heat transfer coefficient in Btu/(h.ft^2 °F)

D= Flow diameter, inches (4)

G= Mass velocity, lb/(s.ft^2)

C_p = Specific heat, Btu/(lb.°F)

Solve this equation to express the heat transfer coefficient in kcal/(h.m^2 .°C). With D is in m, G is in kg/(s.m^2) and Cp in kcal/(kg.°C)

B) Identify the empirical formula of an organic compound with the following mass analysis: Carbon - 26.9%, Hydrogen - 2.2%, and rest is Oxygen. (3)

C) An aqueous solution of $CaCl_2$ (Mw: 111 g/mol) has concentration of 250 ppm. Examine the concentration in normality. (3)

2) An aqueous solution of NaCl contains 20% NaCl. The density of the solution is 1.16 g/mL. 250 ml of pure water is added to 1 litre of 20% NaCl aq. Solution. Determine the molality and molarity of the resulting solution. (3)

A)

B) A flue gas containing 18% CO_2 enters an absorber at 120 kPa and 400 K. Only CO_2 is absorbed and the gas leaves the unit at 95 kPa and 310 K containing 2% CO_2. Assuming that 100 m^3 of gas is admitted to the unit, estimate the (a) volume of gas leaving in m^3, and (b) weight of CO_2 absorbed in kg (3)

C) 0.05 kg of a slightly soluble salt is mixed with 0.1 kg of water. The undissolved salt is removed by filtration. The filter cake weighed 0.045 kg as obtained and 0.040 kg after drying. Estimate the solubility of the salt in water in kg salt/100 kg water? (4)

3) Soybean seeds are extracted with hexane in batch extractors. The flaked seeds contain 20% oil, 68% solids and 12% moisture. At the end of the extraction process, the cake is separated from the hexane-oil mixture. The cake analysis yields 0.8% oil, 88% solids, and 11.2% moisture. Determine the percentage recovery of oil. (3)

A)

B) In a two-stage process, acetic acid is extracted from acetic acid-water mixture using hexanol in an extractor unit and the extract is subsequently separated using distillation. A mixture of 18 wt% acetic acid and balance water is fed to the extractor unit. 100 kg of pure hexanol was used for the extraction of acetic acid. The water rich stream leaving the extractor is 99.5 wt% water and balance acetic acid. The hexanol rich extract was fed to the distillation column. In the distillation column, the distillate stream contains 96 wt% acetic acid and balance hexanol, and the bottom stream contains 97.2 wt% hexanol and balance acetic acid. Also, 95% of the hexanol fed to the extractor was recovered in the bottom stream. Evaluate the % recovery of acetic acid and hexanol from the process. Assume that water is insoluble in hexanol (3)

C) If the humid volume of gas (air-water vapor mixture) at 101.325 kPa and 333 K is 1.05 m^3/kg dry air, determine the following:

(a) Absolute humidity

(b) Wet bulb temperature (4)

(c) % Humidity of the air

(d) % Relative humidity of the air

4) The synthesis of ammonia proceeds according to the following reaction

$N_2 + 3H_2 \rightarrow 2NH_3$

A) In a given plant, 4202 lb of nitrogen and 1046 lb of hydrogen are fed to the synthesis reactor per hour. Production of pure ammonia from this reactor is 3060 lb/h. (3)

(a) Identify the limiting reactant?

(b) Determine the percent excess reactant?

(c) Determine the percent conversion obtained (based on the limiting reactant)?

B) A gas analysed 6.4% CO_2, 0.1% O_2, 39% CO, 51.8% H_2, 0.6% CH_4 and 2.1% N_2. It entered the combustion chamber at 305 K and 118.5 kPa and was burned with 40% excess air (dry), which was at 99.5 kPa and 294 K. After combustion, 10% of the CO remained unburned. Estimate the (a) volume of air (ft^3) supplied per cubic foot of entering gas and (b) volume of product gas produced per cubic foot of entering gas if the exit gas was at 99.5 kPa and 477 K. (3)

C) In the synthesis of ammonia fresh feed containing 24.75% N_2, 74.25% H_2 and 1% inerts (on mole basis) is mixed with recycle feed. Mixed feed entering into the reactor resulted in 25% conversion to ammonia. The product mixture is passed through a condenser, where ammonia gets condensed and the remaining gases are recycled after purging a small portion of the gas stream to avoid build-up of the inerts. The recycle stream contains 12.5% of inerts. Evaluate the (4)

a. Recycle ratio (moles recycled per moles fed)

b. Purge ratio (Moles of purge per moles of recycle)

c. Combined feed ratio (moles fed to reactor per moles of makeup feed)

5) Determine the heat of reaction for the following reaction

$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

A) The standard heat of formation of the compounds are as follows: (3)

$C_5H_{12} = -146.4$ kJ, $CO_2 = -393.98$ kJ, and $H_2O = -241.826$ kJ

B) Using Hess's law, estimate the value for ΔH for the following reaction? (3)

$CS_2(l)+3O_2(g) = CO_2(g) +2SO_2(g)$

Given:

$C(s)+O_2(g) = CO_2(g)$; $\Delta H_f = -393.5$ kJ/mol

$S(s)+O_2(g) = SO_2(g)$; $\Delta H_f = -296.8$ kJ/mol

$C(s) +2S(s) = CS_2(1)$; $\Delta H_f = 87.9$ kJ/mol

C) Determine the heat of the following gas-phase reaction

$H_2 + ½ O_2 \rightarrow H_2O$; $\Delta H^0_{298} = -241826$ J

if the reactants are at 473 K and the product is at 993 K. The specific heats (J/mol K) may be evaluated using the data given below: $C_P = a + bT + cT^2$ (4)

	α	β	γ
H_2	29.09	-8.374×10^{-4}	2.0139×10^{-6}
O_2	25.74	12.987×10^{-3}	-3.864×10^{-6}
H_2O	30.38	9.621×10^{-3}	-1.185×10^{-6}

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