Total No. of Questions :5]

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Roll No

CM - 304

B.E. III Semester Examination, December 2014

Material & Energy Balance

Time : Three Hours

Maximum Marks : 70

Note: i) Answer five questions. In each question part A, B, C is compulsory and D part has internal choice.

ii) All parts of each questions are to be attempted at one place.

iii) All questions carry equal marks, out of which part A and B (Max.50 words) carry 2 marks, part C (Max.100 words) carry 3 marks, part D (Max.400 words) carry 7 marks.

iv) Except numericals, Derivation, Design and Drawing etc.

1. a) If a bucket holds 2.00 lb of NaOH how many
   i) Pound moles of NaOH does it contain.
   ii) Gram moles of NaOH does it contain.
   b) Write the balanced equations for the following reactions
   i) Ammonia reacts with oxygen gas to form nitrogen monoxide and water.
   ii) Iron (III) oxide reacts with carbon (C) to yield iron metal and carbon monoxide.
   c) Define the following terms:
   i) Excess reactant
   ii) Limiting reactant
   iii) Parts per million
   d) The effective heat capacity of a mixture of gases is given by
   $C_p = 7.131 + 0.577 \times 10^{-3}t + 0.0248 \times 10^{-6}t^2$
   Where C_p is in Btu/(lb-mol °F) and t is in °F.
   i) What are the units of the constants in the equation?
   ii) Change the equation into the form in which C_p is given in kJ/(kmol K) and temperature is in K.

OR

250 kg wet ammonium sulphate containing 50 kg moisture is sent to a dryer order to remove 90% of the moisture in the feed. Calculate for the entrance and exit to the dryer, the following:

i) The weight fraction of water
ii) The weight ratio of water
iii) The weight percentage of moisture on a wet basis
iv) The weight percentage of moisture on a dry basis

2. a) A 150 L oxygen cylinder contains gas at 300 K and 10 bar. What is the mass of oxygen in the cylinder?

b) Calculate the pressure developed by one kmol gaseous ammonia contained in vessel of 0.6 m^3 capacity at a constant temperature of 473 K by the following methods:
   i) Using ideal gas equation
   ii) Using the van der Waals equation given that $a = 0.4233\ Nm^4/mol^2$; $b = 3.73 \times 10^{-5}\ m^3/mol$

c) The Antoine constants for n-heptane are A = 13.8587, B = 2911.32, and C = 56.56 P^s is in kPa and T is in K. Calculate
   i) The vapour pressure of n-heptane at 325 K
   ii) The normal boiling point of n-heptane

d) Moist air contains 0.0109 kg water vapour per cubic meter of the mixture at 300 K and 101.3 kPa. Calculate the following:
   i) The partial pressure of water vapour
   ii) The relative saturation
   iii) The absolute humidity of the air
   iv) The percent saturation

The vapour pressure of water is approximated by the Aptoine equation. Antoine constants are A = 16.26205, B = 3799.887, and C = 46.854.

OR

Natural gas is piped from the well at 300 K and 400 kPa. The gas is found to contain 93.0% methane, 4.5% ethane and the rest nitrogen. Calculate:

i) The partial pressure of nitrogen
ii) The pure component volume of ethane in kg/m^3 of the gas
iii) The density at standard conditions in kg/m^3
iv) The density of the gas as piped in kg/m^3
v) The average molecular weight of the gas
vi) The composition in weight percent

3. a) Corn steep liquor contains 2.5% invert sugars and 50% water. The rest of the feed is considered as residual solids. Beet molasses containing 50% sucrose, 1% invert sugar, 18% water and remainder solids are mixed with corn steep liquor in a mixing tank. Water is added to produce a diluted mixture with 2% invert sugar, 125 kg corn steep liquor and 45 kg molasses, which is fed into an enzymatic hydrolysis tank.
   i) How much water is required?
   ii) What is the concentration of sucrose in the final mixture?

b) 1000 kg of mixed acid composition 40% H_2SO_4, 45% HNO_3, and 15% H_2O is to be produced by strengthening waste acid of composition 30% H_2SO_4, 36% HNO_3, and 34% H_2O by weight. Concentrated sulphuric acid of strength 95% and concentrated nitric acid containing 80% are available for this purpose. How many kg of spent acid and concentrated acids are to be mixed together?

c) Explain the following
   i) Bypass
   ii) Purge operation
   iii) Blowdown

d) A fuel oil containing 70% carbon by weight and the rest combustible hydrogen and moisture is burned with excess air. The flue gas analysed 9% CO_2, 2% CO, 3% O_2 and 86% N_2. Determine
   i) The percentage of excess air
   ii) The ratio of carbon to combustible hydrogen in the fuel on a weight basis
   iii) The ratio of carbon to total hydrogen in the fuel on a weight basis
   iv) The percentage of combustible hydrogen and moisture in the fuel.
   v) The mass of moisture present in the flue gas per kg of oil burned.

OR

Air at 320 K saturated with water vapour is dehumidified by cooling to 285 K and by consequent condensation of water vapour. Air leaving the dehumidifier, saturated at 285 K is mixed with a part of the original air which is bypassed. The resulting air stream is reheated to 320 K. It is desired that the final air contains water vapour not more than 0.03 kg per kg of dry air. Calculate:
   i) The mass of dry air (in kg) bypassed per each kg of dry air sent through the dehumidifier.
   ii) The mass of water vapour (in kg) condensed in the dehumidifier per 100 cubic metres of air sent through it.
   iii) The volume of final air obtained per 100 cubic metres of air passed through the dehumidifier.

   The total pressure is atmospheric and the vapour pressure of water are 1.4 kPa at 285 K and 10.6 kPa at 320 K.

4. a) The contents in a stirred tank reactor are being agitated by means of a 2-hp stirrer. The heat generated due to stirring is dissipated to the surroundings at a rate of 3000 kJ/h. Determine the change in internal energy.
   b) Define the terms: heat of fusion and heat of vaporization.
   c) Calculate the standard heat of the following reaction at 298 K.

   $C_3H_{12}(g) + 8O_2(g) \rightarrow 5CO_2 + 6H_2O(l)$

   The standard heats of formation are as follows:

   $CO_2(g) = -393.51$ kJ, $H_2O(g) = -241.826$ kJ, $C_3H_{12}(g) = -146.4$ kJ

   The latent heat of vaporization of water at 298 K is 43.967 kJ/mol.
   d) Methanol is synthesized according to the following reaction:

   $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$

   The standard heats of formation at 298 K are –110.6 kJ/mol for CO and –238.64 kJ/mol for methanol (*l*). The latent heat of vaporization of methanol at 298 K is 37.98 kJ/mol. The specific heats (J/mol K) are given by:

$C_p(CH_3OH) = 18.382 + 101.564 \times 10^{-3}T + 28.683 \times 10^{-6}T^2$

$C_p(CO) = 28.068 + 4.631 \times 10^{-3}T - 2.5773 \times 10^{-6}T^{-2}$

$C_p(H_2) = 27.012 + 3.509 \times 10^{-3}T - 6.9006 \times 10^{-6}T^{-2}$

Calculate the standard heat of reaction at 1073 K.

OR

Caustic soda is concentrated from 10% to 50% in a single effect evaporator. The feed at 305 K enters at a rate of 1000 kg/h. The concentrated solution leaves evaporator at 380 K and the vapour leaves at 373.15 K. Determine the heat to be supplied in the evaporator. The mean heat capacity applicable to the solutions are 3.67 kJ/kg K for the feed and 3.34 kJ/kg K for the product. The heat of solution of 10% and 50% NaOH solution at 298 K are, respectively 42.85 kJ/mol and –25.89 kJ/mol. The latent heat of vaporization of water at 298 K is 2442.5 kJ/mol and the mean heat capacity of water vapour is 1.884 kJ/kg K.

5. a) Wood containing 40% moisture is dried to 5% moisture. What mass of water in kg is evaporated per kg of dry wood?
   b) A crystallizer is charged with 100 kg of a solution containing 25% $Ba(NO_3)_2$ in water. On cooling 10% of the original water present evaporates. Calculate the yield of crystals when the solution is cooled to 283 K. The solubility at 283 K is 7.0 kg $Ba(NO_3)_2$ /100 kg total water.
   c) A continuous distillation column is used to regenerate solvent for use in a solvent extraction unit. The column treats 200 kmol/h of a feed containing 10%(mol) ethyl alcohol and the rest water. The overhead product is 89% (mol) alcohol and the bottom product is 0.3% (mol) alcohol. The overhead is sent to the extraction unit and the bottom is wasted. What is the daily requirement of make-up alcohol in the solvent extraction unit.
   d) Explain crystallization process and write the material balance equation used for the process.

OR

Describe briefly evaporation process and also write the material balance equation for the triple effect evaporator system.

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