

CHUKA



UNIVERSITY

UNIVERSITY EXAMINATIONS

EXAMINATION FOR THE AWARD OF DEGREE OF BACHELOR OF SCIENCE
IN INDUSTRIAL CHEMISTRY

CHIN 313: MATERIALS AND ENERGY BALANCE

STREAMS:

TIME: 2 HOURS

DAY/DATE: TUESDAY 18/4/2023

2.30 P.M. – 4.30 P.M.

INSTRUCTIONS: ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS

QUESTION ONE (30 MARKS)

- a) Explain the following terms:
- i) Fluid flow operations (2 marks)
 - ii) Heat transfer operations (2 marks)
 - iii) Liquid-liquid extraction (2 marks)
- b) Nitrogen gas is confined in a cylinder and the pressure of the gas is maintained by a weight placed on the piston. The mass of the piston and the weight together is 100 lb. The acceleration due to gravity is 9.81 m/s^2 and the atmospheric pressure is one standard atmosphere (1 standard atmosphere = $1.01325 \times 10^5 \text{ N/m}^2$). Assuming the piston is frictionless, determine:
- i) The force exerted by the atmosphere, the piston and the weight on the gas in Newtons, if the piston diameter is 4 inches (3 marks)
 - ii) The pressure of the gas in bar and Psi (3 marks)
 - iii) If the gas is allowed to expand pushing up the piston and the weight by 400 mm, what is the work done by the gas in kJ (1 mark)
- c) How many molecules are present in 691g K_2CO_3 (3 marks)

- d) Define the following terms (4 marks)
- i) Equivalent weight of an element
 - ii) Equivalent weight of an oxidizer
 - iii) Equivalent weight of an acid
 - iv) Equivalent weight of salt
- e) Differentiate between
- i) Molarity and Molality (2 marks)
 - ii) Steady state and Unsteady state (2 marks)
 - iii) Batch and Continuous Process (2 marks)
- f) Write the material balance equation for the process with or without chemical reaction (3 marks)
- g) Define a tie element or key component (1 mark)

QUESTION 2 (20 MARKS)

- a) Iron reacts with steam according to the following reaction
- $$3\text{Fe (s)} + 4\text{H}_2\text{O(aq)} \longrightarrow \text{Fe}_3\text{O}_4 \text{ (s)} + 4 \text{H}_2\text{(g)}$$
- i) How many kilograms of iron and steam are required to produce 100 kg of hydrogen (3 marks)
 - ii) What volume will the hydrogen occupy at standard conditions (1 mark)
- b) 250 cubic meters of 30° API gas oil is blended with 1000 cubic meters of 15 API fuel oil. What is the density of the resultant mixture in kg/m^3 . The density of water at 288.5 K = 999 kg/m^3 . Assume no volume change on mixing (4 marks)
- c) The solubility of sodium Chloride in water at 290K is 35.8 kg/100 kg of water. Express the solubility as the following
- i) Mass fraction and mass percent of NaCl (2 marks)
 - ii) Mole fraction and mole percent of NaCl (2 marks)
 - iii) Kmol NaCl per 1000 kg of water (2 marks)
- d) Discuss the following unit operations and give an industrial application.
- i) Evaporation (2 marks)
 - ii) Leaching (2 marks)
 - iii) Drying (2 marks)

QUESTION 3 (20 MARKS)

- a) Pure water and alcohol are mixed to get a 60% (weight) alcohol solution. The densities (kg/m^3) of water, alcohol and the solution may be taken to be 998, 798 and 895 respectively at 293 K. Calculate the following:
- The volume percent of ethanol in the solution at 293 K (2 marks)
 - The molarity (2 marks)
 - The molality (2 marks)
- b) Wood containing 40% moisture is dried to 5% moisture. What mass of water in kilograms is evaporated per kg of dry wood (4 marks)
- c) 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 composition 30 % H_2SO_4 , 36% HNO_3 and 34% H_2O by weight. Concentrating sulphuric of strength 95% and concentrated nitric acid containing 80% acid are available for this purpose. How many kilograms of spent acid and concentrated acids are to be mixed together (6 marks)
- d) 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 (4 marks).

QUESTION 4 (20 MARKS)

- a) Propane is burned with excess air to ensure complete combustion. If 55 kg of CO_2 and 15 kg of CO are obtained when propane is completely burned with 500 kg air, determine the following:
- The mass of propane burnt (in kilograms) (4 marks)
 - The percent excess air (3 marks)
- b) Define the following terms with respect to combustion:
- Theoretical oxygen (1 mark)
 - Excess oxygen (1 mark)

iii. Net oxygen

(1 mark)

- c) Acetone is recovered from an acetone-air mixture containing 25% (volume) acetone by scrubbing with water. Assuming that air is insoluble in water, determine the percent of acetone in the entering gas that is absorbed if the gas leaving the scrubber analyzes 5% acetone (5 marks)
- d) A crystallizer is charged with 100 kg of a solution containing 25% $\text{Ba}(\text{NO}_3)_2$ 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 $\text{Na}(\text{NO}_3)_2$ /100 kg total weight (5kg)
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