



MACHAKOS UNIVERSITY

University Examinations 2022/2023 Academic year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR SECOND SEMESTER EXAMINATIONS FOR
BACHELOR OF SCIENCE IN ANALYTICAL CHEMISTRY
SAN 306: INDUSTRIAL UNIT OPERATIONS

DATE: 11/4/2025

TIME: 8:30 – 10:30 AM

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks)

QUESTION ONE COMPULSORY (30 MARKS)

- (a). (i) State four critical conditions for setting up a competitive chemical industry. (4 marks)
- (ii) Briefly explain what each condition mentioned above will play in making the established chemical industry to be competitive. (6 marks)
- (b) Chemical industry is entirely constituted of chemical reactions which are processes resulting in the conversion of chemical substances. Describe the following terms as they relate to the chemical process in a chemical industry with the help of examples.
- (i) Chemical reactors. (3 marks)
- (ii) Batch process. (2 marks)
- (iii) Continuous process. (2 marks)
- (c) Distinguish between unit process and unit operation. (3 marks)
- (d) Describe briefly what mass balances are in a chemical process within a chemical Industry. (4 marks)

- (e) The design of a chemical reactor takes into account the following processes, (i) Chemical energetics (ii) Thermodynamics (iii) Safety factors (iv) Economic factors. Mention briefly how each of the foregoing contributes to ensuring the efficient performance of the chemical reactor. (6 marks)

QUESTION TWO (20 MARKS)

- (a) A chemical reaction occurring in a vessel in a laboratory is given by a chemical equation known as a stoichiometric equation e.g., $\text{SO}_2 + \text{O}_2 \longrightarrow 2\text{SO}_3$
- (i) Explain what is stoichiometric coefficient. (2 marks)
- (ii) Define the stoichiometric ratio. (2 marks)
- (iii) What is a limiting reactant in the chemical species fed into a reactor? (2 marks)
- (b) 100 moles of SO_2 and 100 moles of O_2 are fed to a reactor and they react according to the following equation, $2\text{SO}_2 + \text{O}_2 \longrightarrow 2\text{SO}_3$. Determine the:
- (i) Limiting reactant. (2 marks)
- (ii) Excess reactant. (2 marks)
- (iii) Fractional excess. (2 marks)
- (iv) Percentage excess. (2 marks)
- (c) In the reaction $2\text{SO}_2 + \text{O}_2 \longrightarrow 2\text{SO}_3$, 200 moles of SO_2 and 100 moles of O_2 are fed into a reactor. Only 50 moles of O_2 react. Determine the moles remaining for all the remaining species, using the following equation $n_i = n_{i0} + B_i \xi$. First define what these symbols represent. (6 marks)

QUESTION THREE (20 MARKS)

- (a) Chemical reactions may broadly be classified as irreversible and reversible. Explain clearly the difference between the two reactions with the help of equations. (3 marks)
- (b) In a chemical process explain in details the terms yield and selectivity with the help of equations. (4 marks)
- (c) A reactant A of one mole may be transformed into 2 moles of B as a desired product but may also form product C (undesired). 100 moles of A is fed to a batch reactor and the final product contains 10 moles of A, 160 moles of B and 10 moles of C. Calculate,
- (i) Percentage yield of B. (4 marks)
- (ii). The selectivity of B relative to C. (3 marks)
- (iii). The extents of the reactions. (3 marks)
- (d) Differentiate clearly between overall conversion and single pass conversion as related to a process and a reaction in the reactor. (3 marks)

QUESTION FOUR (20 MARKS)

- (a) Manufacturing of phosphate fertilizers from the phosphate rock is another example of a chemical industrial process. The fertilizer plant is normally regarded as a fertilizers' complex plant.
- (i) Write the chemical formula of the phosphate rock. (1 mark)
 - (ii) Why is phosphate fertilizers' plant considered to be a complex? (2 marks)
 - (iii) Name with brief mention of what the various manufacturing plants in the phosphate fertilizers complex plant do. (3 marks)
- (b) Three different types of phosphate fertilizers are produced from the phosphate fertilizers' complex.
- (i) Name the three types of fertilizers. (3 marks)
 - (ii) Briefly describe how the three types of phosphate fertilizers are produced. (3 marks)
 - (iii) What is beneficiation which is one of the steps in the production of phosphate fertilizers? (2 marks)
 - (iv) Write a balanced chemical equation between phosphate rock and sulphuric acid to form phosphoric acid (2 marks)
 - (v) Write a balanced chemical equation between phosphoric acid and phosphate rock in the formation of the triple super phosphate fertilizer. (2 marks)
- (c) Describe briefly the type of waste generated from phosphate fertilizer manufacturing and how it is controlled. (2 marks)

QUESTION FIVE (20 MARKS)

- (a) The industrial production of sulphuric acid is carried out in Contact process.
- (i). State and describe briefly the different sources of elemental sulphur which is the starting raw material in the contact process. (4 marks)
 - (ii) Outline the main steps in the production of sulphuric acid in the Contact process starting with sulphur and ending with the final product. (4 marks)
- (b) From the chemical equation in the formation of one of the intermediates of sulphuric acid manufacturing in Contact process; $\text{SO}_2 + \frac{1}{2}\text{O}_2 \longrightarrow \text{SO}_3$; $\Delta H = -99 \text{ kJ mol}^{-1}$.
- (i). What is the name of the catalyst on which this reaction occurs? (2 marks)
 - (ii). From the thermodynamic and stoichiometric considerations of the above reaction, state **four** ways by which the formation of SO_3 can be maximized. (6 marks)
- (c). Cement is an important material in the construction industry. Outline steps in the manufacture of cement stating the raw materials required. (4 marks)