# NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

**FACULTY OF APPLIED SCIENCE**

**DEPARTMENT OF APPLIED CHEMISTRY**

**UNIT OPERATIONS**

**SCH 2208**

**Examination Paper**

**March 2025**

This examination paper consists of 4 pages

**Time Allowed: 3 hours**

**Total Marks: 100**
**Special Requirements: Graph paper**
**Examiner's Name: Dr. B. Nyoni**

**INSTRUCTIONS**

1. Answer all questions in Section A and any other three questions from Section B
2. Show steps clearly in any calculation
3. Start the answers for each question on a fresh page
4. Use of calculators is permissible

**MARK ALLOCATION**

| QUESTION | MARKS |
|---|---|
| 1. | 20 |
| 2. | 20 |
| 3. | 20 |
| 4. | 20 |
| 5. | 20 |
| TOTAL | 100 |

## SECTION A

**1.** (a) What is a unit operation? [2]

(b) (i) The table below gives three common unit operations that are almost similar in nature. Redraw and fill out the table. [15]

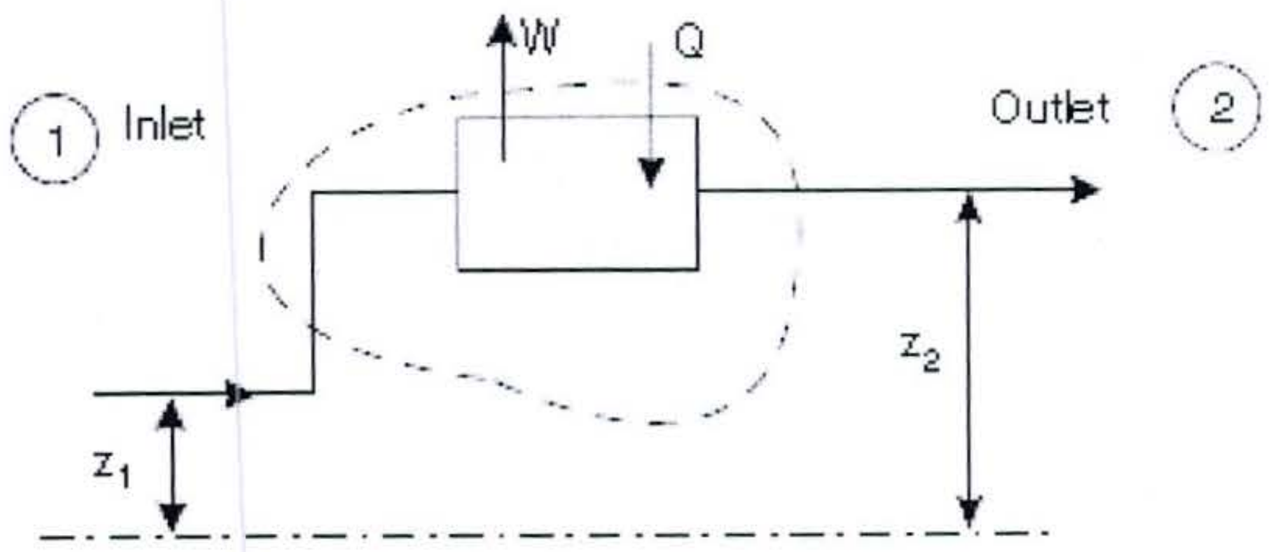
| | Definition | Purpose | Name of equipment |
|---|---|---|---|
| Evaporation | | | |
| Distillation | | | |
| Drying | | | |

(ii) State and explain the transport phenomenon that occurs in the above unit operations? [3]

**2** (a) State the laws of conservation of mass and energy. In what aspects are these laws related. [6]

(b) In which two circumstances do we expect the laws in (a) to fail to hold. Explain your answer. [4]

(c) Consider a steady-state process represented by the figure below. Heat is supplied to the system effecting a temperature increase of 5 K to a 12 kg mass of material with $c_p = 4.2$ kJ/kg.K. The work done to the surroundings is 43 kJ, with no change in the inlet and outlet velocities of the materials. Calculate the change in enthalpy if $z_1$ and $z_2$ are 2 and 16 m respectively.




[10]

## SECTION B

**3** (a) State the three methods of operating evaporators. [3]

(b) A single-effect evaporator is used to concentrate 7 kg/s of a solution from 10 to 50 per cent solids. Steam is available at a temperature of 394K with an enthalpy of 2530 kJ/kg and evaporation takes place at 13.5 kPa and the total enthalpy of steam is 2594 kJ/kg (at this pressure water boils at 325K). If the overall coefficient of heat transfer is 3 kW/m$^2$ deg K, estimate the amount of steam used if the feed to the evaporator is at 294 K and the condensate leaves the heating space at 352.7 K. The specific heats of 10 and 50% solutions are 3.76 and 3.14 kJ/kg.K respectively. [12]

(c) Using sketch diagrams, describe single and multiple effect evaporation system. [3]

(d) State two advantages of multiple effect evaporation compared to single effect evaporation. [2]

**4** (a) State Dalton and Raoult's laws. [4]

(b) A distillation column is fed with a mixture of benzene and toluene, in which the mole fraction of benzene is 0.35. The column is to yield a product in which the mole fraction of benzene is 0.95, when working with a reflux ratio of 3.2, and the waste from the column is not to exceed 0.05 mole fraction of benzene. Estimate the number of plates required. The equilibrium data is given on the table below.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Mole fraction of benzene in liquid (x) | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
| Mole fraction of benzene in vapour (y) | 0.20 | 0.38 | 0.51 | 0.63 | 0.71 | 0.78 | 0.85 | 0.91 | 0.96 |

[14]

(c) List two industrial applications of distillation. [2]

**5.** (a) Leaching is commonly used in gold processing to recover gold from ores. Describe the following methods

(i) heap leaching
(ii) vat leaching [8]

(b) In a pilot scale test using a vessel 1 m$^3$ in volume, a solute was leached from an inert solid and the water was 75 per cent saturated in 100 s. If, in a full-scale unit, 500 kg of the inert solid containing, as before, 28 per cent by mass of the water-soluble component, is agitated with 100 m$^3$ of water, how long will it take for all the solute to dissolve, assuming conditions are equivalent to those in the pilot scale vessel? Water is saturated with the solute at a concentration of 2.5 kg/m$^3$. [8]

(c) What will be the effect on leaching time if the particle size is increased. Explain your answer. [4]

**6** (a) State three reasons for drying products from a manufacturing plant. [3]

(b) A wet solid is dried from 25 to 10 per cent moisture under constant drying conditions in 15 ks (4.17 h). If the critical and the equilibrium moisture contents are 15 and 5 per cent respectively, how long will it take to dry the solid from 30 to 8 per cent moisture under the same conditions? [12]

(c) Describe how a rotary kiln drier operates. [5]

***END OF QUESTION PAPER!!!***