



**NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY**  
**DEPARTMENT OF APPLIED CHEMISTRY**  
**BACHELOR OF SCIENCE HONOURS DEGREE**  
**END OF SECOND SEMESTER EXAMINATIONS – MAY 2013**  
**UNIT OPERATIONS – SCH 2208**  
**TIME: 3 HOURS**

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**Instructions to candidates:**

1. Answer all questions in Section A and any three questions in Section B.
2. Show all your steps clearly in any calculation
3. Start the answers for each question in a new page.

**Extra material:**

1. Graph paper
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**SECTION A**

**1 (a)** What do you understand by the following terms:

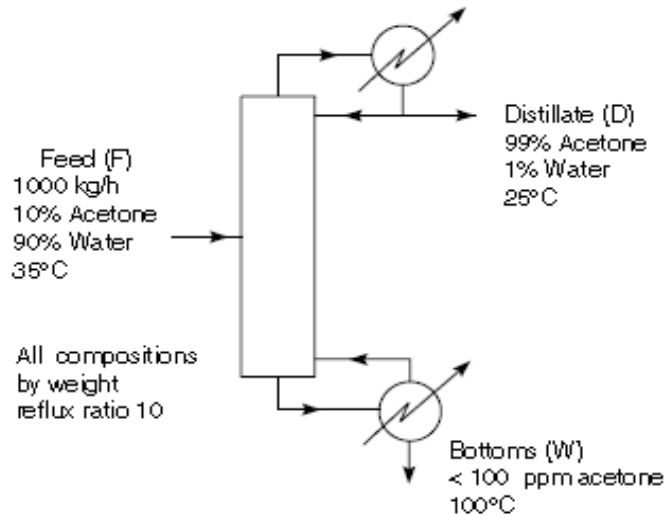
- (i) Evaporation
- (ii) Distillation
- (iii) Leaching
- (iv) Drying
- (v) Absorption [10]

(b) Give and describe practical examples of the application of any three of the above unit operations. [10]

**2 (a)** State the law of conservation of mass. In what circumstances does this law fail to hold? [4]

(b) For the distillation column shown in Fig. 1, assume no chemical reaction occurs in the column. The rise in cooling water temperature is limited to 30 °C. Column operates at 1

bar. The energy supplied to the reboiler is 286 kW. The condenser is in the form of a heat exchanger with cooling water flowing through the shell. Perform mass and energy balance calculations to determine: (i) bottoms and distillate product flows (ii) the amount of heat that must be removed in the condenser and (iii) the cooling water flow. Specific heat capacity of the feed stream (F) and water (W) is 4.0 and 4.2 kJ/kgK respectively.



**Fig 1**

[16]

## SECTION B

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

[3]

(b) A single-effect evaporator is used to concentrate 17 kg/s of a solution from 10 to 45 per cent solids. Steam is available at a temperature of 394K with enthalpy of 2530kJ/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). The overall coefficient of heat transfer is 3 kW/m<sup>2</sup> deg K, the feed to the evaporator is at 294 K and the condensate leaves the heating space at 355 K. The specific heats of 10 and 50% solutions are 3.76 and 3.14 kJ/kg deg K respectively. The specific enthalpy of condensed steam is 4.18 KJ/KgdegK.

Estimate:

- (i) the amount of steam used and
- (ii) the area of heat transfer for the evaporator.

[10]

(c) With the aid of diagrams, explain the terms (i) single effect and (ii) multiple effect evaporators.

[6]

(d) State one advantage of multiple effect evaporation compared to single effect evaporation.

[1]

4 (a) Explain the term azeotrope.

[3]

(b) State Dalton and Raoult's laws.

[4]

(c) 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. If the plate efficiency is 60 per cent, estimate the number of plates required. The relation between the mole fraction of benzene in liquid and in vapour is given in Table 1:

**Table 1**

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

[13]

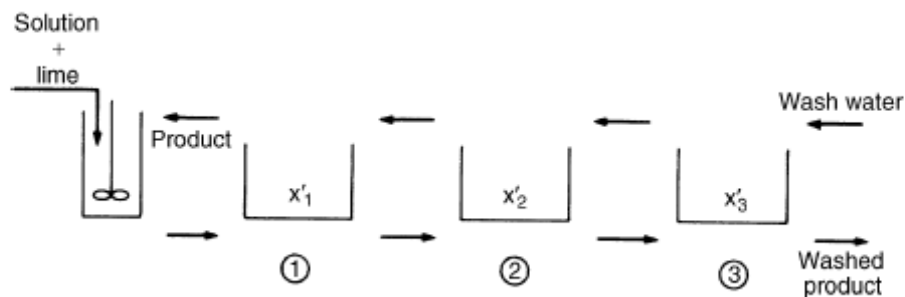
5 (a) State and explain any three factors that affect the rate of leaching.

[6]

(b) Describe, with use of a diagram if necessary, any one leaching equipment of your choice.

[4]

(c) Caustic soda is manufactured by the lime-soda process. A solution of sodium carbonate in water, containing 0.25 kg/s  $\text{Na}_2\text{CO}_3$ , is treated with the theoretical requirement of lime, and after the reaction is complete the  $\text{CaCO}_3$  sludge, containing 1 part of  $\text{CaCO}_3$  per 9 parts of water, by mass, is fed continuously to three thickeners in series and washed counter-currently, as shown in Fig. 1.2. Calculate the necessary rate of feed of neutral water to the thickeners so that the calcium carbonate, on drying, contains only 1 per cent of sodium hydroxide. The solid discharged from each thickener contains 1 part by mass of calcium carbonate to 3 of water. The concentrated wash liquid is mixed with the contents of the agitator before being fed to the first thickener.



**Fig. 2**

[10]

6 (a) Discuss the following terms:

(i) Free moisture.

(ii) Bound moisture.

(iii) Humidity.

[6]

(b) A 100 kg batch of granular solids containing 30 per cent moisture is to be dried in a tray drier to 15.5 per cent of moisture by passing a current of air at 350 K tangentially across its surface at a velocity of 1.8 m/s. If the constant rate of drying under these conditions is  $0.0007 \text{ kg/s m}^2$  and the critical moisture content is 15 per cent, calculate the approximate drying time. Assume the drying surface to be  $0.03 \text{ m}^2/\text{kg dry mass}$ ?

[10]

(c) Describe any one industrial equipment used for drying.

[4]

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