NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY
DEPARTMENT OF APPLIED CHEMISTRY
BACHELOR OF SCIENCE HONOURS DEGREE
SUPPLEMENTARY EXAMINATIONS – AUGUST 2014
UNIT OPERATIONS – SCH 2208
TIME: 3 HOURS

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

SECTION A

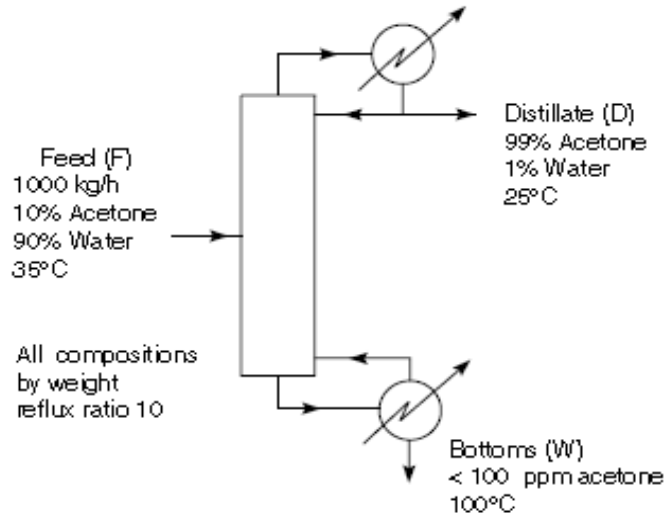**1** (a)   Describe/define the following unit operations:

(i)   Evaporation

(ii)   Liquid-liquid extraction

(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 $30^{o}C$. Column operates at 1 bar. The energy supplied to the re-boiler 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.

Feed (F)
1000 kg/h
10% Acetone
90% Water
35°C

Distillate (D)
99% Acetone
1% Water
25°C

All compositions
by weight
reflux ratio 10

Bottoms (W)
< 100 ppm acetone
100°C

Fig 1

[16]

SECTION B

3 (a) A single-effect evaporator is used to concentrate 17 kg/s of a solution from 10 to 45 percent 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^2 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.K respectively. The specific enthalpy of condensed steam is 4.18 KJ/kg.K.

   Estimate:
   (i) the amount of steam used and
   (ii) the area of heat transfer for the evaporator.   [10]

   (b) With the aid of diagrams, explain the terms (i) single effect and (ii) multiple effect evaporators.   [6]

   (c) In a multiple effect evaporation system, state and explain the method of operation you would choose for the last evaporation stage.

[4]

4 (a) What is the difference between distillation and evaporation. [4]

(b) List ay two materials commonly used for the construction of distillation columns. [2]

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

(d) The vapour pressures of n-heptane and toluene at 373 K are 106 and 73.7 kN/m^2 respectively. What are the mole fractions of n-heptane in the vapour and in the liquid phase at 373 K if the total pressure is 101.3 kN/m^2 [10]

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 Na_2CO_3, is treated with the theoretical requirement of lime, and after the reaction is complete the $CaCO_3$ sludge, containing 1 part of $CaCO_3$ per 9 parts of water, by mass, is fed continuously to three thickeners in series and washed counter-currently, as shown in Fig. 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.
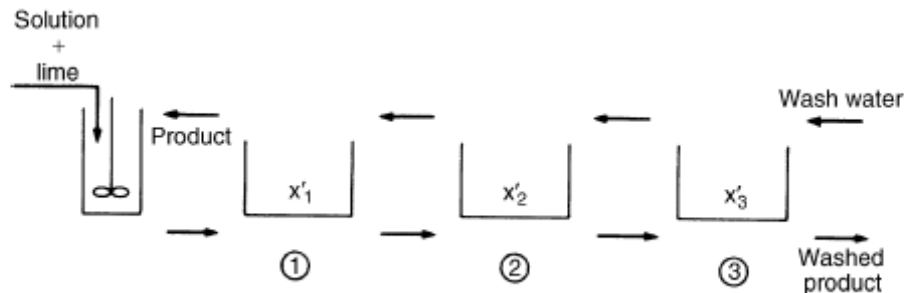

Fig. 2 [10]

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 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 m^2/kg dry mass? [10]

(c) Describe any one industrial equipment used for drying. [4]

END OF QUESTION PAPER!!!