UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

B.Eng. *M.Eng.*

Chemical Eng E869: Particulate Systems and Separation Processes

COURSE CODE	:	**CENGE869**
UNIT VALUE	:	**0.50**
DATE	:	**10-MAY-06**
TIME	:	**14.30**
TIME ALLOWED	:	**3 Hours**

06-C0229-3-70

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*Answer **FOUR** questions. Only the first **FOUR** answers will be marked.*
*ALL questions carry a total of **20 MARKS** each, distributed as shown* [ ]

1.

(i) The effect of a surfactant at an interface is often represented by the *surface pressure* π:

$$\gamma = \gamma_0 - \pi$$

where γ is the surface tension in the presence of the surfactant and γ_0 is the surface tension without the surfactant. Give a simple physical description of how the concentration of the surfactant in the surface region gives rise to this surface pressure effect. How does this surface pressure compare with the conventional concept of a gas pressure in 3 dimensions? [5]

(ii) A cleaning solution is prepared by dissolving a small quantity of a non-ionic surfactant S in water. The solution is left in contact with air. Sketch a diagram to show how the concentration of S at equilibrium changes on passing from the bulk solution phase, through the water-air interface, and into the bulk air phase. Using this sketch, or otherwise, define and explain the concept of the *surface excess concentration* of a surfactant. [5]

(iii) Show that for the simple binary solution above, the general expression of the Gibbs Adsorption Isotherm:

$$d\gamma = -\sum_i \Gamma_i d\mu_i$$

may be reduced to: $\Gamma_s = -\frac{C_s}{RT} \cdot \frac{d\gamma}{dC_s}$

C is bulk concentration (kmol m^{-3}), Γ is the surface excess concentration (kmol m^{-2}), and μ the chemical potential; subscript s refers to the surfactant compound, and the summation over the subscripted i refers to all (both) components in the system. R is the Universal Gas constant and T the absolute temperature. Recall that the chemical potential of a solute i is related to its activity in solution by:

$$\mu_i = \mu_{i,st} + RT \ln a_i$$

and that in dilute solutions activity a_i and concentration C_i are approximately equivalent. $\mu_{i,st}$ is the chemical potential of component i at a standard temperature (298K). Explain clearly any further assumptions you make in this derivation. [6]

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(iv) Starting with the above reduced isotherm equation, show that the equation of state for an *ideal adsorbed layer* can be written as:

$$\Gamma_s = \frac{\pi}{RT}$$

Indicate clearly the assumption relating to ideality that is made in deriving this expression. [4]

2.

(i) Define a chromatography process. Discuss briefly the separation mechanisms for the following two chromatographic processes:

a) Ion exchange chromatography

b) Size exclusion chromatography [4]

(ii) A pharmaceutical company is using isopropanol as a solvent in some of its crystallisation processing steps. To ensure sustainable operation of the plant, the company has decided to re-use the isopropanol and must therefore treat all the solvent streams. A continuous single stage pervaporation plant is to be designed and is required to treat 480 m^3 per day of a solvent mixture of isopropanol and water containing on average 85vol% isopropanol. (The density of water is 1000 kg m^{-3} and the density of isopropanol is 780 kg m^{-3}.) The company can re-use the isopropanol as a solvent provided the mixture is concentrated to 99.5 vol% isopropanol.

To determine the retention of the membrane and the flux through the membrane, a batch lab-scale pervaporation unit using the same membrane as in the proposed continuous plant, is used to separate the solvent mixture. The membrane used in the lab-scale unit is a circular flat sheet membrane with diameter 25 cm, the amount of feed is 2 litres and the concentration is the same as in the continuous unit, *i.e.* 85 vol% isopropanol. At the end of the batch run, which lasts 5 hrs, a total of 0.2 litres of permeate has been collected with a permeate concentration of 0.5 vol% isopropanol.

Calculate the retention of the membrane, the flux (in kg m^{-2} hr^{-1}) through the membrane and the retentate volume (litres) and the retentate concentration (vol%) at the end of the batch. [5]

(iii) Calculate the flow rates (in m^3 hr^{-1}) and concentrations (in vol%) of the feed, the retentate and the permeate in the continuous unit assuming the same membrane is used as in the batch lab-scale unit, *i.e.* with the same retention and flux. Also calculate the required membrane area.
(If you were not able to determine these values in part (ii), use a retention of 0.995 and a flux of 0.7 kg m^{-2} hr^{-1} (These are not the values sought in (ii)). [7]

CONTINUED

(iv) The continuous plant is constructed but the performance of the membrane is found to decrease over time. After a certain period of time, the retentate product purity is found to be only 95 vol% isopropanol. Calculate the actual flux (in kg m^{-2} hr^{-1}) at this time and discuss *briefly* possible causes for this reduction in performance. Which measures, in terms of design and/or operation, would you suggest to take to ensure that the product specification is always met? [4]

3.

(i) Industrial particulate products are often non-spherical and must be characterised for size and shape. Define the terms:

a) equivalent aperture size,
b) equivalent spherical diameter,
c) surface shape factor,
d) volume shape factor, and
e) sphericity

[10]

(ii) Spray-dried detergent powder approximating to spheres 200 *μm* in diameter is to be reconstituted as granules approximating to rods 1.5 *cm* long and 0.5 *cm* in diameter for marketing as *Superwash*. Calculate:

a) the equivalent spherical volume diameter of the rods,
b) their corresponding surface and volume shape factors, and
c) the approximate number of spheres in the rods assuming a void fraction of 0.5.

[10]

4.

(i) State the *population balance* and show that the *crystal size distribution* from a continuous MSMPR crystallizer at steady state is given by:

$$n(L) = n^o \exp(-L / G\tau)$$

where *n(L)* is the population density at crystal size *L*, *G* is the overall linear growth rate (= *dL/dt*) and τ is the mean residence time in the vessel.

[10]

(ii) A 10 m^3 crystallizer is operated with a throughput of 20 m^3h^{-1} and the product crystal size distribution measured (not shown).
If the slope of a log-linear plot of the data = -2×10^{-2} (μm^{-1}) and the intercept = 3×10^{8} ($\mu m^{-1}m^{-3}$), estimate:

a) The crystal growth rate.
b) The nucleation rate.

[10]

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5.

(i) Describe with the aid of a simple sketch the operating principle of the batch filter press and derive describing equations based on Darcy's Law for operation at a) constant pressure, and b) constant rate, stating any assumptions that you may make. [10]

(ii) A batch filter is used to separate a new solid pharmaceutical compound *Kureital* from a solid-liquid suspension. During the first part of the cycle the flowrate is constant and 20 litres is collected in 10 minutes at which time the pressure reaches a maximum.

Estimate for how long the filtration should continue to collect a further 50 litres during the constant pressure period.

[You may ignore the resistance due to the filter medium].

[10]

END OF PAPER