# 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 | : | **13-MAY-03** |
| TIME | : | **10.00** |
| TIME ALLOWED | : | **3 Hours** |

03-C0197-3-50

*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) A *surfactant* is a substance that significantly alters the surface tension at a liquid interface at low concentration. Explain briefly how this occurs. What molecular structure characteristics must the surfactant compound possess in order to function efficiently? [5]

(ii) The effect of a surfactant at an interface can be expressed as the surface pressure $\pi$:

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

where $\gamma$ is the surface tension in the presence of the surfactant and $\gamma_0$ is the surface tension without the surfactant. Give a simple physical description of this surface pressure effect, and compare this quantity with the conventional concept of pressure in three dimensions. [4]

(iii) For dilute solutions of non-ionic surfactants at constant temperature, the Gibbs adsorption isotherm for the liquid-air interface may be written as:

$$\Gamma_s = -\frac{C_s}{RT} \cdot \frac{d\gamma}{dC_s}$$

where $\Gamma_s$ is the surface excess concentration of the surfactant at the interface ($kmol.m^{-2}$) and $C_s$ is the concentration of the surfactant in the bulk liquid ($kmol.m^{-3}$). R is the Universal Gas Constant and T the absolute temperature.

Starting with this 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 assumptions relating to ideality that are made in deriving this expression. [5]

(iv) The following table shows measured values of the surface tension of hydrocinnamic acid in water at 21.5°C:

| Concentration ($kmol.m^{-3}$) | 0 | 0.46 | 0.83 | 1.21 | 1.72 | 2.04 | 2.52 | 3.15 |
|---|---|---|---|---|---|---|---|---|
| Surface tension ($mN.m^{-1}$) | 72.8 | 69.1 | 66.5 | 63.6 | 59.3 | 56.1 | 53.0 | 47.2 |

**CONTINUED**

By plotting surface pressure against concentration, or otherwise, show that the adsorbed layer in this case is approximately ideal. Hence, derive a numerical value for the constant B in the expression:

$$\Gamma_s = B.C_s$$

R = 8.314 x $10^3$ J. $kmol^{-1}$ $K^{-1}$. Absolute zero temperature is – 273.15°C. [6]

**2.**

a) A reverse osmosis (RO) plant is required to treat 4.8 $m^3$ per day of a solution of sucrose in water with 3 weight% of sucrose. The stream has to be concentrated to 10 weight% sucrose. It can be assumed that the solutions in the feed, permeate and retentate streams all have the same density as water, *i.e.* 1000kg/$m^3$. The plant is operated 24 hours a day. The process is to be designed for a single RO recirculation stage. An aromatic polyamide membrane with a retention R of 0.995 will be used in the unit.

i) To determine the flux through the membrane, a test cell with an area of 50 $cm^2$ at 5 bar and 20°C is used to separate the sucrose-water solution. The permeate collection is found to be 10 mg of sucrose in 60 min. Find the flux (in kg/$m^2$hr) through the membrane. [3]

ii) Draw a sketch of the process. [2]

iii) Find the flowrates (in $m^3$/hr) and concentrations (in kg/$m^3$) of the feed, the retentate and the permeate. [5]

iv) Find the required membrane area. [3]

v) 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 8 weight% sucrose.

1 – Find the actual flux (in kg/$m^2$ hr) at this time.
2 – Discuss *briefly* what the possible causes are for this reduction in performance.
3 – Which measures, in terms of design and/or operation, would you suggest to take, to ensure that the product specification is always met? [3]

**CONTINUED**

b)

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

i) Ion exchange chromatography
ii) Size exclusion chromatography [4]

**3.**

a) Show how the size of a non-spherical particle may be expressed in terms of an equivalent spherical particle and explain its utility. [5]

b) Define the terms:

i) equivalent aperture size,
ii) equivalent spherical diameter,
iii) surface shape factor,
iv) volume shape factor, and
v) specific surface area [5]

c) Crystals approximating to briquettes 100 μm long x 5 μm in square cross-section are produced in a precipitation process. Calculate:

i) the equivalent spherical volume diameter of the crystals,
ii) their corresponding surface shape factor,
iii) their volume shape factor, and
iv) their specific surface area. [10]

**4.**

a) Describe, with the aid of sketches, how solids content affects the batch settling of a particulate slurry in terms of its

i) settling velocity
ii) mass flux [5]

b) Derive a simple expression for estimating the required area of a gravity thickener based on settling rate data. [5]

**CONTINUED**

c) An aqueous effluent stream containing 3.5% w/w (solids/slurry) of solid particles is to be clarified leaving behind a sediment of concentration of not more than 5 kg water per kg solids. Laboratory settling tests using six different slurry concentrations yielded the following data:

| Water content (kg $H_2O$/kg solids) | 5 | 10 | 15 | 20 | 25 | 30 |
|---|---|---|---|---|---|---|
| Sedimentation rate (mm/s) | 0.15 | 0.18 | 0.24 | 0.33 | 0.40 | 0.66 |

In order to separate 20, 000 kg/day of solids (dry basis) in continuous operation, calculate

a) the approximate diameter of a suitable cylindrical thickener (m)
b) the fraction of water removed (%).
[Density of water = 1000kg/m$^3$]. [10]

5.

a) Describe, with the aid of a simple sketch, how a batch filter press works. [5]

b) Derive describing equations based on Darcy's Law for operation of a batch filter at

i) constant rate, and
ii) constant pressure. [5]

c) A new pharmaceutical process has been developed and it is proposed to use an existing batch filter to separate the solid from the slurry. A laboratory batch filter 'leaf' test was carried out on a sample of slurry with the following results:

| Time (s) | Filtrate collected ($m^3 10^{-6}$) |
|---|---|
| 0 | 0 |
| 195 | 150 |
| 425 | 250 |
| 570 | 300 |

Test filter area = 0.05 m$^2$
Vacuum applied = 25.0 kN/m$^2$

**CONTINUED**

If the full-scale filter has an area of 10 $m^2$ and is operated at constant rate for 20 minutes after which time the pressure drop is 500 $kN/m^2$ and is maintained at that pressure for a further 30 minutes, what would be the expected

i) initial,
ii) overall average, and
iii) final

filtration rates? [10]

**END OF PAPER**