# 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**

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|---|---|---|
| COURSE CODE | : | **CENGE869** |
| UNIT VALUE | : | **0.50** |
| DATE | : | **10-MAY-02** |
| TIME | : | **10.00** |
| TIME ALLOWED | : | **3 hours** |




**TURN OVER**

UNIVERSITY OF LONDON

Chemical Engineering

# E869

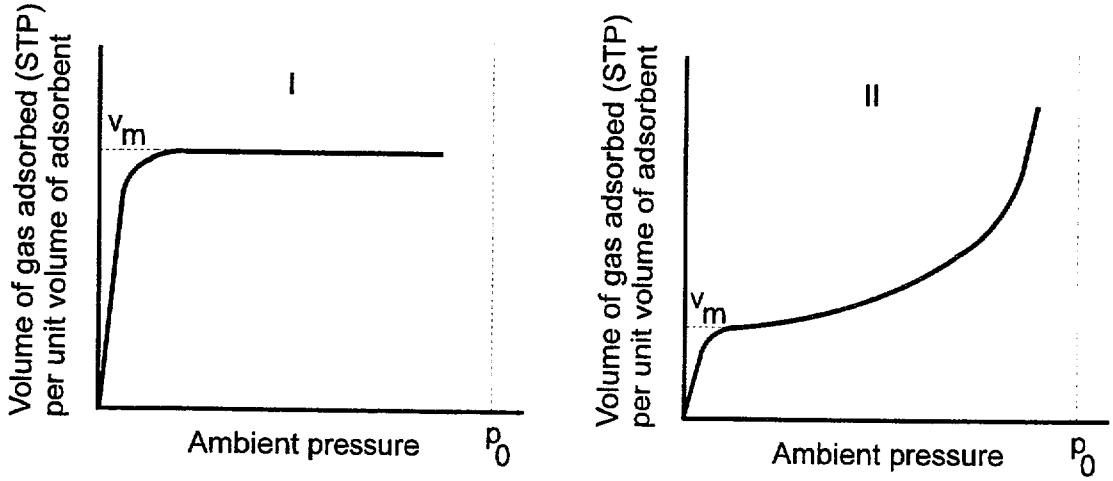
Particulate Systems and Separation Processes

*Answer **FOUR QUESTIONS** only, at least **ONE** from each section.*
*ALL questions carry a total of **20 MARKS** each, distributed as shown* [ ]

**SECTION A**

**1.** a) Describe briefly the terms *physisorption* and *chemisorption* that are applied to the adsorption of a gas on to a solid surface. Outline the basic characteristics that differentiate physisorption from chemisorption. [4]

b) The Figure below shows adsorption isotherms of Brunauer Types I (Langmuir isotherm) and II (sigmoid isotherm).




Briefly describe the types of adsorption behaviour that give rise to these isotherms. [4]

c) The equation of the Langmuir (Type 1) isotherm is: $\frac{v}{v_m} = \frac{ap}{1+ap}$

where
$p$ is the ambient pressure of the gas being adsorbed,
$v$ is the volume of gas adsorbed per unit weight (or volume) of the solid adsorbent,
$v_m$ and $a$ are constants at the given temperature.

Given a set of measured values of $p$ and $v$, show how the above equation may be rearranged to test whether the Langmuir adsorption model is applicable, and, if it is, to determine values of $v_m$ and $a$. What is the physical significance of $v_m$? [4]

d) The following equilibrium data were measured for the adsorption of ammonia on activated charcoal at 250 K:-

| p [$kN.m^{-2}$] | 20 | 40 | 60 | 80 | 100 |
|---|---|---|---|---|---|
| v [$m^3(STP).kg^{-1}$] | 0.1081 | 0.1311 | 0.1446 | 0.1538 | 0.1538 |

Construct a suitable graphical plot to verify that these data comply with the Langmuir isotherm model, and hence determine the values of $v_m$ and $a$. [8]

**TURN OVER**

2. a) What is the definition of : i) a membrane and ii) a membrane module? Two of the main desired attributes of membranes are high permeability and high selectivity. Define permeability and selectivity. [4]

b) Commercial membrane modules are based on the following membrane configurations: tubular, hollow fibre, plate-and-frame and spiral wound. Which configuration has the highest packing density and how high can the packing density be for this configuration? Which configuration has the highest fouling tendency? [3]

c) An ultrafiltration plant is required to treat 50 $m^3$ per day of a protein-containing waste stream with 0.05 weight% of protein. The stream has to be concentrated to 2 weight% so as to allow recycling to the main process stream. Tubular membrane modules are available as 30$m^2$ modules. Assume operation for 20 hr each day. The process is to be designed using a single recirculation stage.
The flux through the membranes (*m/h*) is given by:
$J = 0.02 \ln(30/c_r)$
where $c_r$ is the protein concentration (retentate) in $kg/m^3$. However, due to fouling, the flux never exceeds 0.04 *m/h*.

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

ii) Find the feed, permeate and retentate flowrates (in $m^3/h$) and the feed permeate and retentate concentrations of the protein (in $kg/m^3$). [2]

iii) Find the required membrane area. [2]

iv) Find the minimum number of modules needed to achieve the separation. [2]

d) An aqueous solution of two components A and B is to be separated in a chromatographic column. The sorption isotherms are assumed to be linear and independent and the empirical constants $K_i$ in the linear isotherm are found from experiments to be 0.25 and 0.40 for components A and B, respectively. The superficial solution velocity is 0.03 cm/s and the bed void fraction is 0.30. The feed pulse is 100 s.

i) Find the solute wave velocities of the two components in the column. [2]

ii) Find the minimum length of the column packing to separate the two solutes. [3]

**TURN OVER**

## SECTION B

**3.** Write brief notes on *The Formation and Characterisation of Particulate Solids.* [20]

**4.** Explain with the aid of a sketch how a rotary vacuum (ROVAC) filter works. [5]

Derive describing equations to predict the ROVAC's filtration performance in terms of volume of filtrate and filter cake obtained respectively. [5]

A continuous ROVAC filter is fitted with a two speed gear box. If the drum rotates at 0.1 Hz a filtrate flowrate of 0.02 $m^3/s$ is achieved.

If the second gear doubles the shaft speed, what is the consequent effect on

a) filter cake production rate [5]

b) filter cake thickness. [5]

[Neglect the resistance of the filter medium and assume that the cake is incompressible.]

**5.** Describe the motion of a solid particle settling in a liquid and discuss the effect on it of applying a centrifugal force. [5]

Define the terms *Separating Effect*, $G$, and *Sigma Factor*, $\Sigma$, as applied to centrifuges, and explain their meaning. [5]

Derive simple expressions for $G$ and $\Sigma$ for a thin cylindrical solid bowl centrifuge, carefully stating any assumptions that you may make. [5]

Estimate the magnitude of $G$ and $\Sigma$ for a machine 2 $m$ long by 0.5 $m$ in diameter operating with a liquid depth of 0.05 $m$ and rotating at 100 $Hz$. [5]

**END OF PAPER**