UNIVERSITY COLLEGE LONDON

University of London

EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

Coll Dip M.Eng.

Chemical Eng E875: Advanced Material Processes and Product Engineering

COURSE CODE	:	**CENGE875**
UNIT VALUE	:	**0.50**
DATE	:	**11-MAY-04**
TIME	:	**10.00**
TIME ALLOWED	:	**3 Hours**

04-C0197-3-40

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Answer question 1 (PART A), one question from Part B and two questions from Part C; *in total four questions.*

*The maximum mark of question 1 **(PART A)** is **30 marks**, distributed as indicated* [ ].
*The maximum mark of each question of **Part B** is **20 marks**, distributed as indicated* [ ].
*The maximum mark of each question in **Part C** is **15 marks**, distributed as shown* [ ].
*The total maximum mark is **80**.*

PART A

1.

Derive the following equation for the solubility, expressed as mole-fraction, of a solid compound (2) in a supercritical fluid (1):

$$y_2 = \frac{P_2^{sat}}{P} \frac{\varphi_2^{sat} \exp\{ \int_{P_2^{sat}}^{P} \frac{\upsilon_2^s}{RT} dP\}}{\varphi_2}$$

where P_2^{sat} is the sublimation pressure of 2 at the temperature T, P is the total pressure, φ_2^{sat} is the fugacity coefficient of 2 as saturated vapour at temperature T, φ_2 is the fugacity coefficient of 2 in the supercritical phase at temperature T, υ_2^s is the molar volume of component 2 as a solid and R is the universal gas constant (R = 8.314 J mol^{-1} K^{-1} = 83.14 bar cm^3 mol^{-1} K^{-1}). [7]

The fugacity coefficient φ_2 is given by the following formula using the Peng - Robinson Equation of State:

$$\ln \varphi_2 = \frac{b_2}{b_{mix}}\left(\frac{pV_m}{RT} - 1\right) - \ln\left(\frac{p(V_m - b_{mix})}{RT}\right)$$

$$- \frac{a_{mix}}{2\sqrt{2} b_{mix} RT}\left(\frac{2\sum_i y_i a_{i2}}{a_{mix}} - \frac{b_2}{b_{mix}}\right) \times \ln\left(\frac{V_m + \left(1+\sqrt{2}\right)b_{mix}}{V_m + \left(1-\sqrt{2}\right)b_{mix}}\right)$$

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1. continued

Making reasonable assumptions simplify this formula to the following one:

$$\ln \varphi_2 = \ln\left(\frac{RT}{(V_m - b_1)P}\right) + \frac{b_2}{b_1}\left(\frac{PV_m}{RT} - 1\right)$$

$$-\frac{a_1}{2\sqrt{2}RTb_1}\left(\frac{2a_{12}}{a_1} - \frac{b_2}{b_1}\right)\times\ln\left(\frac{V_m + \left(1+\sqrt{2}\right)b_1}{V_m\left(1-\sqrt{2}\right)b_1}\right)$$ [4]

Use the equation for the solubility and the above simplified formula for φ_2, in order to calculate the solubility of a component (2) with the following properties in supercritical CO_2 (1), at two temperature levels, 305 K and 315 K, and two pressures, 65 bar and 80 bar, each time (four sets of conditions):

P_2^{sat} at 305 K: 6.5 x 10^{-6} bar, P_2^{sat} at 315 K: 12.9 x 10^{-6} bar,
υ_2^S = 138.2 cm^3 mol^{-1}

Critical Pressure and Temperature of component 2: 30 bar and 826 K
Accentric factor of component 2: $\omega_2 = 0.406$.
Additional Data: Critical Pressure and Temperature of CO_2: 73.8 bar and 304.1 K
Accentric factor of CO_2: $\omega_1 = 0.225$
Interaction coefficient between CO_2 and 2: k_{12}=0.09
In order to calculate φ_2 you may use the *PV* plot for CO_2 on the following page.

[15]

Calculate the ratios of the solubility at 80 bar over this at 65 bar for both temperatures. Compare the ratios and comment on your results. [4]

For any part of question 1, you may use the following equations:

$$\ln \varphi_2 = \int_0^P \left[\frac{\overline{\upsilon_2}}{RT} - \frac{1}{P}\right] dP$$

Peng - Robinson Equation of State:

$$P = \frac{RT}{V_m - b} - \frac{a}{V_m^2 + 2bV_m - b^2}$$

where $a = \frac{0.45724RT_c^2}{P_c}\left(1 + f\omega\left(1 - \sqrt{\frac{T}{T_c}}\right)\right)^2$

CONTINUED

1. continued

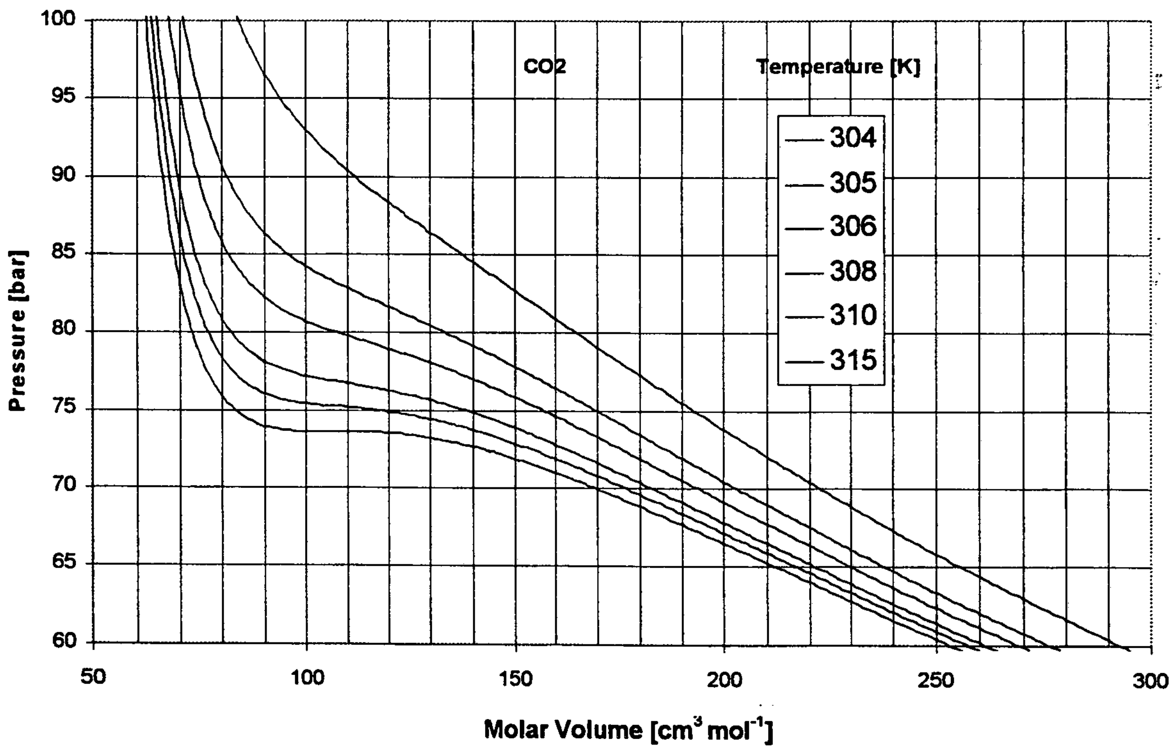
$$f\omega = 0.37464 + 1.54226\omega - 0.26992\omega^2$$

$$b = \frac{0.07780RT_c}{P_c}$$

$$b_{mix} = \sum_i y_i b_i$$

$$a_{mix} = \sum_i \sum_j y_i y_j a_{ij}(1 - k_{ij})$$

$$a_{ij} = (a_i . a_j)^{1/2}$$



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PART B

2.

How do red phosphorus and phosphorus compounds act as a flame retardant? [6]

Halogen–containing formulations are widely used as flame retardants. Explain their retardation mechanism and why attempts are being made to replace them. [6]

Describe the general mechanisms involved in polymer decomposition. [4]

What is meant by the following terms in relation to chain-scission mechanisms:

i) Intramolecular H-Transfer
ii) Intermolecular H-Transfer

Use reaction schemes in your answer. [4]

3.

Explain the principle of lithography, as well as the terms positive and negative resist. [6]

Draw a typical sensitivity curve and define the term contrast for both resist types. [4]

Derive an equation describing the dependence of the average molar mass of the resist upon the radiation dose in lithography. [7]

Define the characteristic quantity *G* and explain how it can be estimated. [3]

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PART C

4.

a) What is a concept combination table? Explain how it works, its usefulness and useful guidelines. [5]

b) Name and briefly describe the steps of concept screening and concept scoring. Explain the differences between the corresponding steps. [10]

5.

a) Name and briefly explain the ways of prototypes classification. [4]

b) Name and briefly discuss the five principles of prototyping. [7]

c) Name and briefly discuss the steps in planning for prototypes. [4]

6.

a) Give a schematic overview of the Design for Manufacturing (DFM) methodology. [5]

b) In the framework of DFM, describe briefly the methodology for estimating manufacturing costs. Explain the terms of fixed costs and variable costs. What is the bill of materials? [10]

END OF PAPER