國立中央大學106學年度碩士班考試入學試題

所別：　化學工程與材料工程學系 碩士班 甲組(一般生)　　共3頁　第1頁
科目：　輸送現象與單元操作
本科考試可使用計算器，廠牌、功能不拘　　＊請在答案卷內作答

如有計算題請列出計算過程

參考用

1. (10%) For flow through conduits of various shapes, what factor(s) influence the friction factor? Give the answers for both laminar flow and turbulent flow.

2. (25%) Find the volumetric flow rate Q for the axial flow of a power-law liquid through a slit of width W, thickness $2B$, and length L under a pressure drop $\mathscr{P}_0 - \mathscr{P}_L$ (with $B << W << L$).

   For a power-law fluid, $\tau_{xz} = -m\left|\frac{dv_z}{dx}\right|^{n-1}\frac{dv_z}{dx}$

   Note: If you can't solve this problem for a power-law liquid, you can solve this problem for a Newtonian liquid with constant viscosity μ instead. However, you will not get full score for this problem.

3. (15%) A countercurrent tower operating at 300 K and atmospheric pressure is used to reduce component A from a gas stream from 0.04 (kmol A / kmol of inert components) to 3 per cent of this value by solvent scrubbing. The equilibrium relation for the solution may be approximated as $Y_e = 2.5\,X$.

   The solvent enters the tower free of A and leaves containing 0.015 kmol of A/kmol of solvent. If the flow of inert gas is 0.017 kmol/s m^2 of tower cross-section, calculate:

   (a) (7%) the height of the absorber necessary, and

   (b) (8%) the number of transfer units N_{OG} required.

   The overall coefficient for absorption $K_G''a$ may be taken as 0.03 kmol/s m^3.

4. (20%) A commercially sold moth-ball is suspended in an enclosure with no apparent draft and slowly sublimes, releasing vapor into the surrounding air by a molecular diffusion-limited process. Assuming the moth-ball is made completely of naphthalene with no porosity and is spherical, determine how many hours it would take to reduce the diameter from 3.0 to 1.5 cm when the surrounding air is at 60°C and 1.0 atm. Useful naphthalene data:

   Molecular weight: 128 g/mol
   Solid density: 1.145 g/cm^3
   Diffusivity in air: 8.19x10^{-6} m^2/s
   Vapor pressure at 60°C: 245 Pa

注意:背面有試題

5. (30%) Proteins are all-important molecular machines carrying out vital cellular processes in cells. To decipher the working principles of the machines, one crucial step is to solve their molecular structures, and X-ray crystallography is one of the most powerful techniques in this regard. A crystallography experiment is carried out on a single crystal of the interested protein. X-rays which are illuminated on and subsequently diffracted by a crystal are collected for solving the protein structure. Ideally, the stronger the diffraction signals are, the better the quality of the obtained diffraction data would be and the higher the resolution of the solved structure can achieve. However, strong diffraction signals are often attained by exposing a crystal to X-rays for an extended time, which is detrimental to a crystal. This detrimental effect arises from the energy absorption by a crystal and is known as radiation damage. One way radiation damage wreaks havoc is by increasing the temperature of a crystal. Therefore, to address the issues associated with radiation damage, we must understand how a crystal is heated by X-rays. Consider the following situations.

(a) (6%) If our crystallography experiment is conducted at room temperature (27 °C) with a crystal exposed to 10 keV X-rays (1 keV $\approx 1.6 \times 10^{-16}$ J) in the photon flux of 1×10^{13} photons/s·mm^2, what will be the surface temperature of the crystal when a steady state is reached (the absorptivity for 10 keV x-rays of the crystal is 0.08, its emissivity is 0.8 and heat convection to the air is assumed to be negligible)? (Hint: the energy carried by each photon is 10 keV; the surface emissive power is given by $E = \varepsilon\sigma T^4$, where $\sigma = 5.67 \times 10^{-8}$ W/m^2·K^4)

To avoid overheating the crystal to the high temperature specified in (a), the X-ray exposure time of the crystal must be limited.

(b) (6%) Following the condition in (a) and assuming that the crystal density is 1.2×10^{-3} g/mm^3, its specific heat is 6 J/g·K, its volume is $0.2\times0.2\times0.2$ mm^3 (all temperature-independent), the crystal absorbs X-rays uniformly and the X-ray beam covers one side of the crystal *exactly*, what is the upper limit of the exposure time within which the surface temperature of the crystal will never exceed 40 °C, a temperature where we run a high risk of thermally disrupting the protein's native structure?

However, the exposure time determined in (b) is too short to collect a complete dataset. To extend the allowable exposure time, a common practice is to place a crystal under a steady stream of cold N_2 gas when the crystal is exposed to X-rays. We then consider a situation where the crystal described in (a) and (b) is placed under a N_2 gas stream of 100 K, which is flowing at 1.5 m/s and in the direction normal to one face of the crystal (the cross section of the stream is far larger than the crystal size). Boundary layers are expected to form by the gas stream on the crystal surfaces, which are crucial to the consideration of the heat transfer between the gas stream and crystal.

(c) (6%) With the thickness of the velocity boundary layer given by $\delta = 5x/\sqrt{Re_x}$ (x is the distance from the leading edge of the crystal surface parallel to the gas stream) and the Prandtl number and kinematic viscosity for N_2 at 100 K being 0.69 and 1.9×10^{-6} m^2/s, respectively, what is the thickness of the temperature boundary layer, δ_t? What is the physical meaning of a Prandtl number?

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(d) (12%)Given the relation, $\bar{h} \approx k/\delta_t$, where $\bar{h}$ is the average heat transfer coefficient (assumed to be temperature-independent), k is the thermal conductivity (which is 9.8×10^{-3} W/m·K for N_2 at 100 K) and δ_t is as calculated in (c) and following the condition in (b), what is the upper limit of the exposure time within which the temperature of the crystal *core* will never exceed 30 °C? (Hint: Determine the Biot number first and frame your strategy of attacking the problem accordingly)