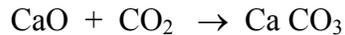


10.302
Fall 2004
Discussion Problems for Recitation on
Tuesday, December 7, 2004

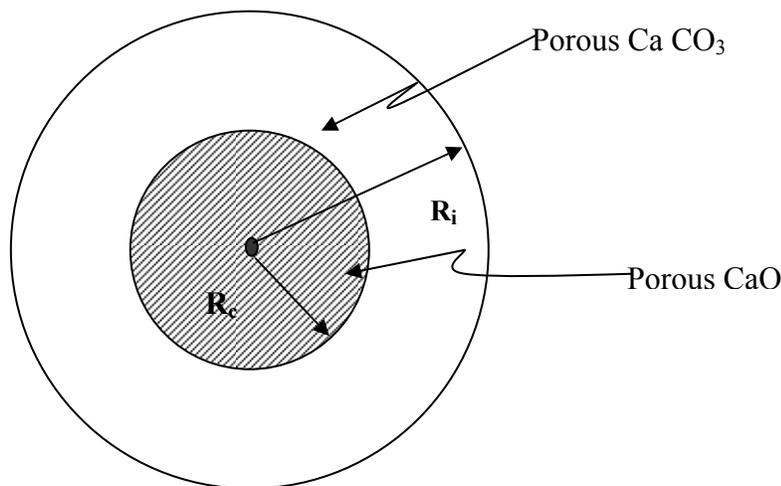
Problem 1

Porous spherical pellets of CaO (MW = 56) are to be used to remove dilute CO₂ from a gas stream in accordance with



The reaction is irreversible and fast, so it has been proposed that a shrinking core model be used to determine the lifetime of a pellet. In the shrinking core model, there is a sharp interface between the fully reacted shell and the fully unreacted core (see sketch). The reaction is limited by diffusion in the porous shell and it is assumed that the concentration profile is quasi-steady. Under these conditions, the concentration of CO₂ at $r = R_c$ is zero.

- a. Obtain the quasi-steady concentration profile in the shell as a function of $C_{\text{CO}_2}(R_i)$, D_{eff} , R_i , R_c , etc.
- b. Obtain an expression for the lifetime of a pellet in terms of R_i , D_{eff} , $C_{\text{CO}_2}(R_i)$, etc.
Evaluate your result for $R_i = 5\text{mm}$, $D_{\text{eff}} = 0.1\text{ cm}^2/\text{s}$
($=10^{-5}\text{m}^2/\text{s}$), $X_{\text{CO}_2}(R_i) = 0.01$, $\rho_{\text{app}} = \text{apparent density of porous solid} = 1000\text{ kg/m}^3$,
 $\rho_{\text{Gas}} = 1\text{ kg/m}^3$.
- c. Is the quasi-steady assumption appropriate? Why?



Problem 2

A detector for the presence of combustible vapors in an air stream is to be constructed in the following fashion: A platinum wire is to be placed in the air stream and it will be heated electrically. If combustible vapors are present, the platinum wire will catalyze the reaction to CO_2 and H_2O . In fact, it may be assumed that the catalyst is ideal, i.e. the reaction at the surface of the wire will be complete. In such a case, the wire will heat up, its electrical resistance will increase, and the wire temperature will be inferred by measuring the electrical resistance of the wire.

- (a) At standard conditions of air velocity, heating current, etc., but in the absence of combustible vapors, it is found that the wire temperature is 700K. The temperature of the air stream is 310K. At otherwise identical conditions, but in the presence of a combustible gas, the wire temperature is found to be 805K. Please estimate the mass fraction combustible gas which is present in the air. Neglect radiation for this purpose.
- (b) The wire has a diameter of 0.2mm and an emissivity of 0.9. The air velocity perpendicular to it is 3 m/s. Pressure is one atm. Roughly estimate the importance of radiation.

Notes:

(i) The heat of combustion of the fuel is 45×10^6 J/kg

(ii) Properties of air

$$k = 0.036 \text{ W/m}\cdot\text{K}$$

$$\rho = 0.82 \text{ kg/m}^3$$

$$c_p = 1010 \text{ J/kg}\cdot\text{K}$$

$$D_{\text{Fuel}/\text{Air}} = 4 \times 10^{-5} \text{ m}^2/\text{s}$$

$$\nu = 3 \times 10^{-5} \text{ m}^2/\text{s}$$

HINT: Use energy balances at the surface of the wire for both standard and reactive conditions.