Correlation of liquid dispersion and oxygen transfer in bubble column*

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Summary. In steady state, attained by continuous aeration after oxygen saturation of water in a bubble column, vertical composition distribution of liquid and gas phases has been determined. It has been assumed that, as a result of absorption at the bottom of the column, desorption in the upper section and vertical dispersion of dissolved oxygen flux, a closed oxygen circulation is created. Determination of the axial dispersion coefficient from hydrodynamic and oxygen transfer data verifies the mathematical model proposed. The results allow conclusions to be drawn about supersaturation and desorption and other phenomena expected in biological systems.

Introduction

Transfer coefficients \( k_L a \) and \( k_L \) describe the steric average of oxygen transfer rate in the contactor studied. In a bubble column, however, along the length of the column, unanimous pressure profile and owing to the plug flow behaviour of the gas phase (Urza 1975; Jackson et al. 1975; Jackson and Shen 1978) unanimous bubble-age and oxygen content distribution can be observed. This involves a change in gas-liquid equilibrium and, owing to isothermal expansion, a change in the interfacial area and the driving force of transfer.

As a result of mixing, however, homogenization of the liquid phase prevents the development of height dependence of measurable transfer rate.

It may be assumed that in a high bubble column, complex oxygen transfer processes are also affected by supersaturation. Water height and supersaturation, measured at the liquid surface of the column or basin, are also known to be correlated (Gilbert and Libby 1977). This supports the assumption that the parameters obtained may also be due to local oxygen desorption. It is evident from the above that determination of a \( k_L a \) type rate constant derived from a rather simplified mathematical model is not sufficient for the description of the process. Determination of the local oxygen content of the phases is also required. This leads to the determination of actual driving forces of oxygen transfer, resulting in correct \( k_L a \) values.

Experimental investigations of the complex problem were based on the recognition of two facts: 1. After an unsteady state aeration test with bubbling at unchanged superficial gas velocity, a new steady state sets in, where mole fractions of input- and output oxygen are identical. Phase composition distributions in depth can be maintained without any time limit, which ensures safe conditions of measurement. The relative position of phase composition curves is determined by absorption and desorption, mixing of the liquid
phase and vertical one-dimensional diffusion. The probe used for the measurement of dissolved oxygen level can be used, with dry membrane, for the measurement of oxygen partial pressure in gas phase at any depths in a flow-through cell.

**Materials and methods**

The bubble column under investigation had an internal diameter of 152 mm and a height of 4 m. Attached to the upper end was a tank (internal diameter) 400 mm the aim of which is to reduce the increase in liquid height resulting from gas hold up. The air flow measured by a flowmeter has been introduced through 28 holes (~) forming a sparger.

The cell containing electrode is a 27 mm (4) cylinder sealed at the top, equipped below the membrane with three layers of gauze for droplet separation and connected to an off gas tube bent to the water level desired. To the lower orifice of the cylinder, we fitted a funnel with a diameter proportional to gas flow, resulting, in 30—40 cm³ total gas volume, in a short response time suitable also for dynamic measurements. For the analysis of both gas- and liquid composition, two Radelkisz OH-503 type membrane-dissolved-oxygen meters have been used. The composition was given in terms of dimensionless \( C' \) and \( C'' \): where 0.21 bar oxygen partial pressure, or dissolved oxygen level in equilibrium with latter was considered as unit,

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C' = \frac{x}{x_{atm}}
\]

where \( x \) is the signal registered in the experiment and \( x_{atm} \) the signal recorded in \( O_2 \) saturated water, or water vapor saturated air stream, at a temperature identical to the experiment under atmospheric pressure.

Upon the onset of steady state in the column, by parallel transfer of liquid- and gas probes, at each gas velocity 9—9 data have been registered at distances of 0.5 m. The results given represent average values (in good agreement) of two series of measurements taken in reverse directions. The crude results of liquid phase \( k_{l,a} \) measurements in unsteady state have been corrected by a mean 5.18 s response time of the measuring system (Conseiller et al. 1977) and by the formula that takes into account the oxygen decrease in gas phase (Kayser 1979).

The \( E \) axial dispersion coefficient characterizing liquid phase mixing was determined by recording the conductivity of the expansion of 5 N NaCl tracer solution instantaneously fed 3.68 m away from the detection point.

Evaluation was made by application of the one-dimension diffusion model extended to columns without liquid feed (Sawinsky and Borus 1978).

**Results and discussion**

\( C' \) values of phase composition distributions are presented as a function of height in Fig. 1. Liquid curves numbered 1—9 are by order of succession assigned to gas velocities \( u \) of 0.153—3.29 cm/s. Of the gas phase (broken line) curves, only those assigned to the two extreme \( u \)-values are presented. At \( y=0 \) point of the gas phase curve “9”, the value of \( C'_g < 1.4 \) is due to the expansion curve “9”. The value of \( C'_g < 1.4 \) is due to the expansion tank. At increasing gas velocities, liquid displacement by gas entrapment causes the tank gradually to become filled; this leads to reduction in pressure at the bottom of the column. As can be seen, the in-