Short Communication

Physical significance of the mass transfer coefficient

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I wish to show that the mass transfer coefficient, if properly defined, has a simple physical significance, hitherto unrecognized in the chemical engineering literature.

There are various definitions of the mass transfer coefficients which emanate from the defining relationship

$$\text{Flux} = \text{Factor} \times \text{mass transfer coefficient} \times \text{driving force} \tag{1}$$

As shown very clearly by Bird *et al.* [1], the flux of the transferring species is most conveniently chosen with respect to the average velocity of the mixture rather than with respect to a stationary laboratory-fixed frame of reference. Many choices of the mixture velocity are possible, *e.g.* mass average, molar average and volume average velocities. The choice of the mixture velocity is closely linked to the choice of the driving force. Let us draw some clues from the analogous problem of definition of the molecular diffusion coefficient. As shown by Bird *et al.*, if we define the molecular diffusivity D in a binary mixture by any of the following three defining equations

$$J_1 = -c_t D \nabla x_1 \tag{2}$$

$$j_1 = -\rho_t D \nabla \omega_1 \tag{3}$$

$$J_1^{v} = -D \nabla c_1 \tag{4}$$

then the three definitions of D are *identical.* Clearly, if we wish to correlate the mass transfer coefficient with the molecular diffusion coefficient D we must choose analogous definitions

$$J_1 = c_t k \Delta x_1 \tag{5}$$

$$j_1 = \rho_t k \Delta \omega_1 \tag{6}$$

$$J_1^{v} = k \Delta c_1 \tag{7}$$

Let us examine eqn. (5), for example. Using the definition of the molar diffusion flux relative to the molar average velocity

$$k = \frac{c_1(u_1 - u)}{c_t \Delta x_1} = \frac{(u_1 - u)}{\Delta x_1 / x_1} \tag{8}$$

Now

$$|\Delta x_1 / x_1| \leqslant 1 \tag{9}$$

and so

$$k \geqslant (u_1 - u) \tag{10}$$

or in other words, the mass transfer coefficient k represents the *maximum* velocity, with respect to the mixture, with which a component can be transferred. The mass transfer coefficient has not just the dimensions of velocity, but also the same physical significance. Realization of this is helpful for pedagogical purposes.

REFERENCE

1 R. B. Bird, W. E. Stewart and E. N. Lightfoot, *Transport Phenomena*, Wiley, New York, 1960.

APPENDIX A: NOMENCLATURE

c_1	molar density of component 1 (kmol m^{-3})
c_t	molar density of mixture (kmol m^{-3})
D	molecular diffusion coefficient (m^2 s^{-1})
J_1	molar flux relative to molar average mixture velocity u (kmol m^{-2} s^{-1})
j_1	mass flux relative to mass average velocity u (kmol m^{-2} s^{-1})
J_1^{v}	molar flux relative to volume average mixture velocity u^{v} (kmol m^{-2} s^{-1})
k	mass transfer coefficient (m s^{-1})

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u_1 velocity of transferring species 1 in a stationary reference frame (m s^{-1})
u molar average mixture velocity (m s^{-1})
x_1 mole fraction of component 1
Δx_1 mole fraction difference driving force

Greek symbols

ρ_1 mass density of component 1 (kg m^{-3})
ρ_t mass density of mixture (kg m^{-3})
ω_1 mass fraction of component 1
$\Delta\omega_1$ mass fraction difference driving force