This article presents a general analysis of the rate of mass transfer within an agitated liquid phase in contact with a gas phase, with particular attention to the case where diffusion and chemical reaction are occurring simultaneously. At the end of the lecture, some elementary concepts are discussed for the case where the liquid phase contains a suspended solid.

It should be borne in mind that the gas-side resistance to mass transfer, though occasionally negligible, is never zero, and that therefore the overall transfer rate is in general influenced by it. Attention is here restricted to the liquid phase, and the value of the interface partial pressure of the transferring components is regarded as a known quantity. The equations which are derived should be coupled with the equation for mass transfer in the gas phase in order to calculate the overall transfer rate.

The aim is to introduce basic concepts and to establish the general mathematical background. Therefore attention is restricted here to those conditions of simultaneous diffusion and chemical reaction which can be regarded as limiting or asymptotic cases. Significant simplifications may arise, for example, when the chemical reaction is extremely fast or extremely slow, as compared to diffusion phenomena.

Consider the case where a chemical solvent is used in gas treating, so that the liquid phase contains one or more components
Bj(\(j = 1, 2, \ldots, N\)) which may react chemically with the component A which is being either absorbed or desorbed. Usually the components Bj are non-volatile, so that all the chemical reactions take place in the liquid phase.

The occurrence of the chemical reactions has two distinct effects on the overall behavior of the system. The first one is, for the case of absorption, as follows. When component A is absorbed into the liquid phase, it is consumed by the chemical reactions and therefore its concentration in the bulk of the liquid, \(a_i\), is kept low. This in turn implies that the driving force for additional absorption remains higher than it would be if no chemical reaction were taking place. Conversely, in desorption the chemical reaction continuously produces the component to be desorbed, thus providing a high concentration of it in the liquid and a large driving force for the desorption.

The second effect is more subtle. At a given level of driving force, the actual rate of mass transfer may be very significantly larger when chemical reactions are taking place than it would be in the absence of chemical reactions. The rate enhancement may be very large, up to two orders of magnitude or even more. Indeed, the enhancement may be so large as to actually reduce the mass transfer resistance in the liquid phase to the point at which it is negligible as compared to the resistance in the gas phase.

The concept of rate enhancement introduced above is formalized as follows. In the absence of chemical reactions, the mass transfer rate in the liquid phase is given by

\[
N = k_L^0 (a_i - a_o)
\]  

(1)

where \(N\) is the mass transfer flux and \(a_i\) is the interface concentration of A in the liquid phase. The actual rate in the presence of chemical reactions may be larger than the value given by Eq.1; a "chemical" mass transfer coefficient, \(k_L\), can be defined as follows:

\[
N = k_L (a_i - a_o)
\]  

(2)

The rate enhancement factor, \(I\), is defined as the ratio of the actual rate and the rate which would be observed under the same driving force in the absence of chemical reactions:

\[
I = \frac{N}{k_L^0 (a_i - a_o)} = \frac{k_L}{k_L^0}
\]  

(3)