In view of the increasing evidence that multicomponent diffusion effects could be significant in biological gas exchange systems, a non-equimolar film model of multicomponent diffusion was derived. "Osmotic" ternary diffusion was studied for the gas systems He-N₂-O₂, He-SF₆-O₂, and N₂-SF₆-O₂. Diffusional fluxes and concentration profiles were calculated under both the "square-root" and the "product" flux conditions. Results were also compared with those obtained using the equimolar flux condition. It was found that the greater the difference of the diffusibilities between the two active components in a system, the greater the osmotic fluxes, and also the more alinear the concentration profiles. These results support the suggestion that the "product" condition applies to molecular diffusion in free space, the "square-root" condition to molecular diffusion in pores, and the equimolar flux condition to closed diffusion systems.

1. Introduction. All biological gas exchange processes involve more than two gas species. Although the study of multicomponent gas diffusion traces back more than one hundred years (Stefan, 1871), the possible effect of multicomponent gas diffusion in biological systems was not explored until very recently (Chang and Farhi, 1973).

Applying the concept of multicomponent diffusion to respiratory gas exchange and attempting to examine the implications of multicomponent diffusion in the lung, Chang et al. (1975) have made a mathematical study employing a simple film model derived from the general multicomponent diffusion equations (Toor, 1964). The diffusion studied was ternary and was assumed to be equimolar, i.e., the net flux of the three species being zero.
The authors demonstrated not only quantitative but also qualitative differences between binary diffusion fluxes computed from the Fick's law and ternary diffusion fluxes. Among other things, they showed that when helium mixture is used, carbon dioxide may diffuse against its own concentration gradient, namely, reverse diffusion may occur.

Since this mathematical study, several experimental studies have appeared in the biological literature (Erasmus and Rahn, 1976; Modell and Farhi, 1976; Bres and Hatzfeld, 1977; Paganelli and Kurata, 1977; Worth and Piiper, 1978), each relating to the mathematical work by Chang et al. (1975).

However, it is well known that the biological gas exchange systems, such as the incubating avian egg or the human lung, are not restricted to what chemical engineers call "closed systems" (Figure 1). Therefore, equimolar diffusion is generally unlikely to occur. To investigate further the implications of multicomponent diffusion in biological gas exchange, non-equimolar models suitable for open-systems should be used.

Non-equimolar ternary gas diffusion has been studied by Remick and Geankopolis (1970, 1974), Feng et al. (1974), and Patel (1974). These investigators were interested either in the transition region between Knudsen and molecular diffusion or in the characteristics of the porous material through which diffusion occurs. None of these investigators has developed a mathematical model for non-equimolar molecular diffusion.

In this paper, a non-equimolar film model based on the general multicomponent diffusion equations is developed. The model is applied to

Figure 1. Schematic sketches of a closed system and an open system