refers to the reactions described previously, and

$$[C^{\mathrm{Na}}(0) - C^{\mathrm{Na}}(\eta_{\max})]/C^{\mathrm{Na}}(0) = f'(\mathrm{Sc}\,\eta_{\max}) \qquad (7)$$

where 0 and $\eta_{\max}$ refer to the wall and the point of maximum temperature in the boundary layer.

The number 1.0, which appears as the first term of the result in Eq. (6), accounts for the depletion of the trace contaminant; this effect was justifiably not considered by Kane.[1] Depletion was not found important for sodium[3] except at the lowest altitudes and then for very long bodies only; however, it must be considered if the ionizing trace contaminant is cesium. It may be observed that, if depletion is neglected, and the reactions specified by Kane in Fig. 1 of Ref. 1 are assumed, one may obtain the generalized results of that figure (which were obtained by correlating results of numerical integrations) directly from Eq. (6) herein.

References

[1] Kane, J. J., "Nonequilibrium sodium ionization in laminar boundary layers," AIAA J. **2**, 1651–1653 (1964).

[2] Lenard, M., "Ionization of trace species in slender cone boundary layers," AIAA J. **3**, 367–369 (1965).

[3] Lenard, M., "Ionization of cesium and sodium contaminated air in the hypersonic slender body boundary layer," General Electric Co., Space Sciences Lab., Rept. 64SD22 (August 1964).

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[5] Blottner, F. G., "Nonequilibrium laminar boundary layer flow of ionized air," AIAA J. **2**, 1921–1927 (1964).

Reply by Author to M. Lenard

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IT is agreed that the chemical system described by Lenard includes more significant reactions than those originally considered.[1] However, as was mentioned in Ref. 1, the type of analysis employed there can be applied to new ionization reactions as they are identified, just as it is assumed that new chemistry will not invalidate Lenard's work.

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The evaluation of integrals which Lenard's method would eliminate is not that difficult. Requiring only an integration method such as Simpson's rule, the integration can be accomplished by hand or in a very short time on a digital computer. Furthermore, it provides a complete description of the electron density profile which is needed if one is concerned with the attenuation of an rf signal by the plasma sheath. Since he computes the electron density at only one point in the boundary layer, Lenard's analysis cannot be applied to the attenuation problem.

For the calculation of boundary-layer peak electron density, Lenard's proposed expression is indeed simpler, but a word should be said about its range of validity. It is based on the assumption that the mass fraction profiles for all the reaction products all have the same shape and that their peak is coincident with the temperature peak. The separation of these peaks will depend on many parameters such as wall temperature and catalycity, pressure, transport properties, etc. It will also depend on the temperature dependency of the reaction being studied. The suggested rate for the most significant reaction of Ref. 1 was temperature independent so that an appreciable separation of the temperature and sodium ion peaks was noted. Lenard's expression also implies that the electron concentration peak is coincident with the ion mass fraction peak. The validity of this implication of course depends on the manner in which the density varies. In the studies on which Ref. 1 was based, a separation of these two peaks was noted for the temperature-independent reaction so that all told, for the most significant reaction of Ref.1, it was found that the electron concentration at the peak temperature location differed by as much as 50% from the peak electron concentration in the boundary layer.

The main value of Ref. 1 is that generalized quantitative results are presented. Lenard[2] has drawn qualitative conclusions and has presented results for specific calculations. A generalization of his results (as he indicates can be done in the preceding comment) would significantly enhance their utility.

References

[1] Kane, J. J., "Nonequilibrium sodium ionization in laminar boundary layers," AIAA J. **2**, 1651–1653 (1964).

[2] Lenard, M., "Ionization of cesium and sodium contaminated air in the hypersonic slender body boundary layer," General Electric Co., Space Sciences Lab. Rept. 64SD22 (August 1964).