predicted by analogy with the thermal conductivity

$$K = \mu c_v \qquad \text{(IIIE-21a)}$$

A similar procedure can be employed to develop a general expression for the rate of diffusion induced by a concentration gradient within a molecular gas mixture. This expression provides a means to define the diffusion coefficient. However, this development requires consideration of gaseous mixtures; that is, requires techniques of Unit VIA. Since Unit VIA is not a prerequisite to this unit, diffusion is discussed in Appendix A. In the following section we consider momentum and heat transport within molecular gaseous continua.

A. The Transport Properties of Molecular Gases

The viscosity of a perfect molecular gas is determined by substituting eqns. IIIE-5a, 11, and 13b into eqn. IIIE-19a. The result is

$$\mu^* = \frac{2}{3\sigma^+}\left(\frac{MkT}{\pi N_A}\right)^{\frac{1}{2}} \qquad \text{(IIIE-19b)}$$

Exercise 17. Determine the viscosity of oxygen and helium at 100, 300, and 1000 K.

Both the form and numerical results predicted by eqn. IIIE-19b are in satisfactory agreement with data. Similarly, application of eqns. 20a and 21a correctly predicts the form for perfect gases. The numerical predictions, however, are off by a significant factor. This deviation is primarily caused by coupling between the speed, energy and mean free path of the carrier molecules. A more rigorous development would account for the fact that slow moving molecules have less kinetic energy and shorter than average mean free paths and vice versa.[17] These effects have been accounted for by Euken, whose expression for K has the same form but a different numerical coefficient than that of eqns. IIIE-20a or 21a

$$K^* = \frac{(9\gamma^* - 5)}{4}\mu^* c_v^* = \frac{(9\gamma^* - 5)}{6\sigma^+}\frac{k}{(\gamma^* - 1)}\left(\frac{RT}{\pi}\right)^{\frac{1}{2}} \qquad \text{(IIIE-20b)}$$

The analogy between heat and momentum transport is further emphasized by the dimensionless property ratio called the *Prandtl number*, $Pr \equiv \mu c_p/K$. Eqns. IIIE-19b and 20b predict the Prandtl number of perfect gases to be

$$Pr^* \equiv \frac{\mu^* c_p^*}{K^*} = \frac{4\gamma^*}{9\gamma^* - 5} \qquad \text{(IIIE-22)}$$

Exercise 18. Extend the results of Exer. 17 to determine the thermal conductivity and Prandtl number of oxygen and helium at 100, 300, and 1000 K.

[17]The transport flux of kinetic energy is enhanced by a factor of four thirds over that predicted using eqn. IIIE-15, viz., $\dot{e}''_{ke} = \dot{n}''2kT$ rather than $\dot{n}''(3/2)\cdot kT$, see Ref. 4. This correction is not by itself sufficient to obtain Euken's result. The mean free path effect must also be accounted for.