hydrogen atom, Exer. 16, is representative of all atoms and molecules, $\theta_{el} \sim 10^5$K. Thus we can determine the properties of given independent indistinguishable atoms or molecules at ordinary temperatures without regard to the electronic mode.

As the temperature of a gas increases, its electronic mode begins to be excited. Electronic excitation affects the properties of the substance in a manner that is similar to other modes. However, electrons that are sufficiently excited will *dissociate* from the particle creating a *plasma*— a mixture of free electrons and positive ions. This radically changes the electric properties of the gas; it becomes conducting. Thus the electronic mode is significant at somewhat lower excitation levels than other modes. Finally, when particles are altered as a result of a chemical reaction, atoms are shifted from one type of particle to another. This requires dissociation of atoms from the participating molecules. The energy of molecular dissociation is normally reported in terms of electronic energy levels. Thus the change in the electronic partition function is a principal term in the evaluation of the effects of chemical reactions even when the electronic modes of the reactants and their products are unexcited preceding and following the reaction. The use of the electronic mode in the study of ionization and chemical reactions is considered briefly in Appendix IIIC-B.

This concludes the development of the unit. The following section summarizes the contributions of translational, rotation-nuclear spin, and vibrational modes for given particles.

IV. PROPERTIES OF MOLECULAR PERFECT GASES

The preceding sections considered external translation and each internal mode of a molecular gas. We found that property changes that occur to a given substance can be determined considering only its translational, rotational-nuclear spin, and vibrational modes. The necessary data (θ_r, σ and $\theta_{v,p}$) are provided in Table IIIC-2. Analytic expressions for each of the required partition functions Z_{tr}, $Z_{r,n}$ and $Z_{v,p}$ were developed, and the procedures by which their corresponding properties are determined were illustrated by example and exercise. Complete results are summarized in Table IIIC-1. The objective of this section is to combine the effects of the separate modes to determine overall properties. Since our eventual interest lies in property changes we choose to ignore the constants introduced by the electronic, see Appendix IIIC-B, and nuclear binding mode; and we will, therefore, refer to the sum of the translational, rotational-nuclear spin, and vibrational modes as though they were total properties.

Example 10 Write an expression for the partition function, internal energy, enthalpy, specific heats, and entropy of a system of independent, nonlocalized atoms.

We extract the necessary expression for Z, $\bar{u}^*$, $\bar{c}_v^*$, and $\bar{s}^*$ from Table IIIC-1.

$$Z = Z_{tr} Z_{r,n} Z_v = n\bar{v}\left(\frac{2\pi m^* kT}{h^2}\right)^{3/2} \cdot 1 \cdot 1 \qquad \bar{u}^* = \frac{3}{2}\bar{R}T + 0 + 0$$