(Exercise 2, continued) macrostate is an equilibrium macrostate, that is, is it consistent with eqn. IIIB-11? If it is an equilibrium macrostate, what is the system's equilibrium temperature? (c) A second macrostate has $n_2 = 3000$. Is this an equilibrium macrostate?

B. Distribution Functions for Bosons and Fermions

The procedures to derive the distribution functions for Bosons and Fermions are analogous to that used above for Boltzons. One starts with eqn. IIIB-7 which is applicable to all statistics. Specificity is introduced by the substitution of the appropriate expression for W_i, eqns. IIIA-7b or c. The development, including the identification of β as $1/kT$ by the differentiation of the entropy, is presented in Appendix IIIB-B. These results will be employed extensively in Units IIIC and D. Students who continue with these units may wish to examine this derivation. The results for Fermions are

$$n_j^{FD} = \frac{g_j}{e^{\alpha+\varepsilon_j/kT} + 1} \qquad \text{(IIIB-14)}$$

$$S^{FD} = \frac{U}{T} + Nk\alpha + k \sum_j g_j \ln \left[1 + e^{-\alpha-\varepsilon_j(V)/kT}\right] \qquad \text{(IIIB-15)}$$

And for Bosons, the results are

$$n_j^{BE} = \frac{g_j}{e^{\alpha + \varepsilon_j/kT} - 1} \qquad \text{(IIIB-16)}$$

$$S^{BE} = \frac{U}{T} + Nk\alpha - k \sum_j g_j \ln \left[1 - e^{-\alpha-\varepsilon_j(V)/kT}\right] \qquad \text{(IIIB-17)}$$

The identification of the parameter α for these statistics is not easy to accomplish in general. This step is deferred to Units IIIC and IIID, where it is needed for application.

At this point we have evaluated the equilibrium distribution functions for all three types of independent particles. These will enable us to evaluate the properties of substances based on microscopic models. The development was done in terms of isolated systems (fixed U, V, and N). But the conclusions are valid for any system in equilibrium. The results are simply applied to the nonisolated system in terms of its *instantaneous* values of U, V, and N.

III. ENTROPY IN MACROSCOPIC TERMS, THE GIBBS EQUATION

We have formulated the second law in terms of the entropy, eqn. IIIB-5. Our original definition of entropy was in microscopic form, eqn. IIIB-1. In the preceding section we were able to formulate the equilibrium entropy as an analytic function, eqn. IIIB-13, 15 or 17. But the formulation still contains microscopic parameters [$\varepsilon_j(V)$ and g_j].