**Table 6.1** Comparison of the orbital occupancies in the classical and the quantum regimes

| Regime | Class of particle | Thermal average occupancy of any orbital |
|---|---|---|
| Classical | Fermion | Always much less than one. |
| | Boson | Always much less than one. |
| Quantum | Fermion | Close to but less than one. |
| | Boson | Orbital of lowest energy has an occupancy much greater than one. |

arise only for occupancies of the order of one or more, so that in the classical regime their equilibrium properties are identical. The quantum regime is the opposite of the classical regime. These characteristic features are summarized in Table 6.1.

## CLASSICAL LIMIT

**An ideal gas is defined as a system of free noninteracting particles in the classical regime.** "Free" means confined in a box with no restrictions or external forces acting within the box. We develop the properties of an ideal gas with the use of the powerful method of the Gibbs sum. In Chapter 3 we treated the ideal gas by use of the partition function, but the identical particle problem encountered there was resolved by a method whose validity was not perfectly clear.

The Fermi-Dirac and Bose-Einstein distribution functions in the classical limit lead to the identical result for the average number of atoms in an orbital. Write $f(\varepsilon)$ for the average occupancy of an orbital at energy $\varepsilon$. Here $\varepsilon$ is the energy of an orbital occupied by one particle; it is not the energy of a system of $N$ particles. The Fermi-Dirac (FD) and Bose-Einstein (BE) distribution functions are

$$f(\varepsilon) = \frac{1}{\exp[(\varepsilon - \mu)/\tau] \pm 1} , \tag{11}$$

where the plus sign is for the FD distribution and the minus sign for the BE distribution. In order that $f(\varepsilon)$ be much smaller than unity for all orbitals, we must have in this classical regime

$$\exp[(\varepsilon - \mu)/\tau] \gg 1 , \tag{12}$$