The sum $\sum P(s)$ of the probability over all states is always equal to unity, because the total probability that the system is in some state is unity:

$$\sum_s P(s) = 1. \tag{2}$$

The probabilities defined by (1) lead to the definition of the average value of any physical property. Suppose that the physical property X has the value $X(s)$ when the system is in the state s. Here X might denote magnetic moment, energy, square of the energy, charge density near a point **r**, or any property that can be observed when the system is in a quantum state. Then the average of the observations of the quantity X taken over a system described by the probabilities $P(s)$ is

$$\boxed{\langle X\rangle = \sum_s X(s)P(s).} \tag{3}$$

This equation defines the average value of X. Here $P(s)$ is the probability that the system is in the state s. The angular brackets $\langle\cdots\rangle$ are used to denote average value.

For a closed system, the average value of X is

$$\langle X\rangle = \sum_s X(s)(1/g) , \tag{4}$$

because now all g accessible states are equally likely, with $P(s) = 1/g$. The average in (4) is an elementary example of what may be called an **ensemble average**: we imagine g similar systems, one in each accessible quantum state. Such a group of systems constructed alike is called an ensemble of systems. The average of any property over the group is called the ensemble average of that property.

An ensemble of systems is composed of many systems, all constructed alike. Each system in the ensemble is a replica of the actual system in one of the quantum states accessible to the system. If there are g accessible states, then there will be g systems in the ensemble, one system for each state. Each system in the ensemble is equivalent for all practical purposes to the actual system. Each system satisfies all external requirements placed on the original system and in this sense is "just as good" as the actual system. Every quantum state

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