KINETIC EQUATIONS FOR A SYSTEM WEAKLY COUPLED TO A THERMAL BATH

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Kinetic equations are derived for a system weakly coupled to a thermal bath. It is shown that the collision term has the same form as in the generalized kinetic equations for a system with a small interaction. Equations of the type of Redfield's equations for the spin density matrix and the "master" equation are derived. Longitudinal nuclear spin–lattice relaxation is considered as an example and Gorter's relation is derived. The treatment is based on the nonequilibrium statistical operator method developed by Zubarev.

1. Introduction

The present paper is devoted to an investigation of relaxation processes in two weakly interacting subsystems, one of which is in a nonequilibrium state and the other plays the role of a thermal bath. We are interested in the problem of obtaining kinetic equations for a certain set of mean values that characterize the nonequilibrium state of the system. As is well known, generalized kinetic equations, i.e., equations for a certain set of mean values (for example, mean values for the operators of the spin occupation numbers etc.), describing the nonequilibrium state of a system with a small interaction were obtained by Peletminskii and Yatsenko [1] and, by a different method by Pokrovskii [2]. A problem of a system coupled to a thermal bath, similar to the problem considered in this paper, was studied by Pokrovskii [3]. He assumed that the nonequilibrium system was subjected to an external variable field.

In deriving kinetic equations, we shall use the nonequilibrium statistical operator method developed by Zubarev [4, 5]. In the next section, we consider the construction of the nonequilibrium statistical operator and derive kinetic equations for a system coupled to a thermal bath. We show that the expression for the collision term has the same form as in the generalized kinetic equations in [1, 2] but differs from them in that the averaging in the equations is made with allowance for the states of the medium. In Section 3, we used our equations to derive equations in a certain approximation. The structure of these equations resembles Redfield's equations [7] for the spin density matrix. The "master" equation is obtained for a special case. In Section 4, we consider the example of the problem of longitudinal nuclear spin–lattice relaxations and obtain Gorter's relation.

We should point out that equations of the Redfield type were obtained in [3] by means of the nonequilibrium statistical operator method with allowance for an external variable field.

2. Construction of the Nonequilibrium Statistical Operator and Derivation of the Kinetic Equations

Let us consider the relaxation of a small subsystem placed in an equilibrium medium. We shall write the Hamiltonian of the complete system in the form

$$\mathcal{H} = \mathcal{H}_1 + \mathcal{H}_2 + V, \tag{1}$$

where

$$\mathcal{H}_1 = \sum_{\alpha} E_{\alpha} a_{\alpha}^{+} a_{\alpha},$$

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