Quantum Thermodynamics of a Strongly Interacting Bose-Fermi Mixture in a Three-Dimensional Anharmonic Potential

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Abstract
An idealized quantum system is a Harmonic oscillator that obeys Hooke's law. Anharmonic oscillation is a deviation of a system from harmonic oscillation. Bosons are integer spin particles which are governed by Bose-Einstein statistics while fermions are half-integer spin particles governed by Fermi-Dirac statistics. The main objective of the study was to determine thermodynamic properties of a binary mixture of strongly interacting bosons and fermions in a three dimensional anharmonic potential. Objectives of the study are: to determine the internal energy, determine heat capacity at constant volume and determine entropy of a perturbed grand canonical system of ^3He-^4He isotopes. Thermodynamic properties of Bose-Fermi mixture at ultra-low temperatures were studied using perturbation theory in three Cartesian coordinates. The total Hamiltonian for the system was developed in terms of pair interactions. The harmonic oscillator problem was solved from the Hermite equation. MathCAD Professional 200 software was used to generate values and graphs of the variables against temperature. The total internal energy of the binary system was found to increase with increase in temperature. In both first and second excited states the mixture had about 150 joules of energy at about 40 kelvins. Energy value of the mixture in the ground state was found to be about 171.3 joules. The specific heat capacity versus temperature curves showed sharp turning points with different peak values at different temperatures. Entropy of the BF mixture in an excited state was found to increase with temperature, and became constant at higher temperatures but became zero at temperatures near absolute zero. An extra second order correction applied to a quartic perturbation lowers the internal energy of a boson-fermion mixture in an excited state. Perturbation lowers entropy of an excited system. Peak value of specific heat capacity for a higher excited state is lower while transition temperature is higher.

Key words: *Bose-Fermi, Anharmonicity, Perturbation, Grand-canonical, Hamiltonian*