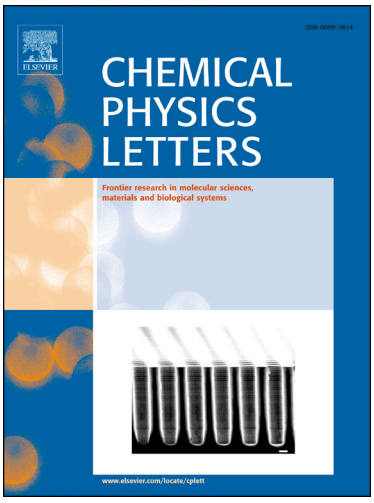

Research paper

Thermodynamic paths for calculating energy balance in systems containing nanoparticles

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Thermodynamic paths for calculating energy balance in systems containing nanoparticles

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Abstract

Size-dependent physicochemical properties of nanoparticles led to certain complications in thermodynamic calculations followed by energy balance as the first step in these calculations. This work reviewed recent studies on nanothermodynamic topics in an attempt to find some thermodynamic methods for establishing energy balance in systems containing nanoparticles. Some thermodynamic paths were introduced to establish energy balance for ease of calculation by avoiding unknown functions. Based on the proposed pathway, enthalpy changes for several processes involving nanoparticles, such as formation of nanoparticles and phase transitions, were investigated and formulated.

Keywords: Energy balance; Systems with nanoparticles; Nanothermodynamics

INTRODUCTION

Nanoscience has achieved significant progress in recent years, especially in various branches of engineering. Nanotechnology can be used to produce new structures, devices, and materials on a near atomic scale. For example, using nanometals in fluids leads to enhancement of heat transfer coefficients and reduces the size of heat exchangers [1]. Nano-filters help to capture nanoaerosols and prevent their emission into the environment [2, 3, 4].

Undoubtedly, the first step to working at the nanoscale level is understanding the thermodynamic behavior of nanoparticles. For the first time, Hill [5] showed that the differential equations of macroscopic thermodynamics can be generalized in such a way that they may also be applied to small (i.e., non-macroscopic) systems. Hill explained that, unlike macroscopic thermodynamics, thermodynamic functions are different for different environments in nonmacroscopic scale. Another important difference noted by Hill was the effect of fluctuations. Fluctuations are negligible in macroscopic thermodynamics; therefore, we can use the mean values of fluctuating extensive variables appearing in thermodynamic equations. Hill and Chamberlin [6] showed how the statistical thermodynamics of small systems could be extended to include metastable supersaturated gaseous states close to the gas-liquid equilibrium transition point. Furthermore, Hill [7] suggested a method to handle a macroscopic system with potential energy (μ), pressure (p), and temperature (T) by starting with the corresponding small system partition function, calculating the thermodynamic properties from this function. Hill [8] also explained two interrelated topics: 1. generalizing