Similarity Theory in Photothermal Experiments: A Condition for Neglecting Convection Effects

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In the last years the application of photothermal methods for the measurement of optical and thermal properties of liquids has become a field of considerable interest. For example, nanofluids, i.e., solid-liquid suspensions of nanoparticles and a base liquid, have received considerable attention due to their potential applications in several fields. One of the most exotic features –sometimes controversial- of these systems is that their thermal conductivity can exceed that of the base fluid and of the fluid with larger particles of the same kind. Therefore, reliable experimental measurement of thermal conductivity is today an impetus as well as the development of methods to the measurement of other physical properties that can help in the modeling of the involved heat transfer mechanisms.

The use of photothermal (PT) techniques can be an alternative in this new developed field of research. In the theoretical models describing photothermal experiments the knowledge of the Temperature within the sample and/or its environment is necessary in order to obtain basic parameters of the analyzed phenomena. For solids it is usually calculated by solving the heat diffusion equation, which is also often used for liquid samples, neglecting the role played by hydrodynamic effects, such as convection. Therefore, we will describe in this work -on the light of the photoacoustic technique- how the Theory of Similarity shows that the heat diffusion equation, in its usual formulation, can be only applied in PT experiments with fluids when the product of the dimensionless Grashof (Gr) and Prandtl (Pr) numbers, the so-called Rayleigh, Ra, number, is lower than 1000.