

Phase transitions in dipole fluids

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Dipole fluids are colloidal systems of magnetic or dielectric particles in carrier liquids. These systems attract considerable interest of investigators and practices due to rich set of physical properties, valuable for many high technologies. The second reason of interest to the dipole fluids is that they can serve as convenient systems to study fundamental physical phenomena in many polar systems.

In order to prevent coagulation of the particles under the colloidal disperse forces, they are covered with special shells, which screen this interaction. It is well known that dipole particles in magnetic, ferroelectric, magnetorheological, etc. fluids can condense into bulk dense phases. This condensation usually is considered a first-kind phase transitions in the system of the dipole particles. Experiments show that external magnetic (electrical) field stimulates this phase transition. The first theories of these phenomena have treated them as the classical "gas-liquid" phase transitions in the systems of dipole particles. However computer and laboratory experiments, carried out for the recent years, demonstrate that before the bulk phase separation the particles form linear chain-like and net-like structures. Appearance of these chains and nets changes significantly the general scenario of the phase transition.

The fundamental question of the phase transition is discussed intensively lately: whether the dipole forces can provide the bulk particle condensation, or these forces can lead only to "polymerization" of the particles and formation of the chains? Are "traces" of the central forces necessary for the bulk condensation? This problem is very important both from the point of view of the general theory of phase transitions and from the point of view of the physics of dipole fluids.

We present results of theoretical study of scenarios of condensation phase transitions in the systems of identical spherical particles with a permanent magnetic moment each. It is taken into account that the linear chain-like aggregates can appear in the system of particles before their bulk condensation. Analysis shows that without external magnetic field this condensation is similar to the classical "gas-liquid" phase transition with the critical point on the binodal. In the case of infinitely strong magnetic field appearance of the chains blocks the "gas-liquid" phase transition; the experimentally observed condensation of particles rather must be of the "gas-solid" type. These results open a question of the influence of the applied field on the type of the phase transition and of the magnitude of the threshold field for the transformation from the "gas-liquid" to the "gas-solid" transition.