

The Phase Diagram of Strongly Interacting Matter

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A fundamental question of physics is what ultimately happens to matter as it is heated or compressed. In the realm of very high temperature and density the fundamental degrees of freedom of the strong interaction, quarks and gluons, come into play and a transition from matter consisting of confined baryons and mesons to a state with "liberated" quarks and gluons is expected. The study of the possible phases of strongly interacting matter is at the focus of many research activities worldwide. In this article we discuss physical aspects of the phase diagram, its relation to the evolution of the early universe as well as the inner core of neutron stars. We also summarize recent progress in the experimental study of hadronic or quark-gluon matter under extreme conditions with ultrarelativistic nucleus-nucleus collisions.

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I. INTRODUCTION

Matter that surrounds us comes in a variety of phases which can be transformed into each other by a change of external conditions such as temperature, pressure, composition etc. Transitions from one phase to another are often accompanied by drastic changes in the physical properties of a material, such as its elastic properties, light transmission, or electrical conductivity. A good example is water whose phases are (partly) accessible to everyday experience. Changes in external pressure and temperature result in a rich phase diagram which, besides the familiar liquid and gaseous phases, features a variety of solid (ice) phases in which the H_2O molecules arrange themselves in spatial lattices of certain symmetries (Fig. 1).

Twelve of such crystalline (ice) phases are known at present. In addition, three amorphous (glass) phases

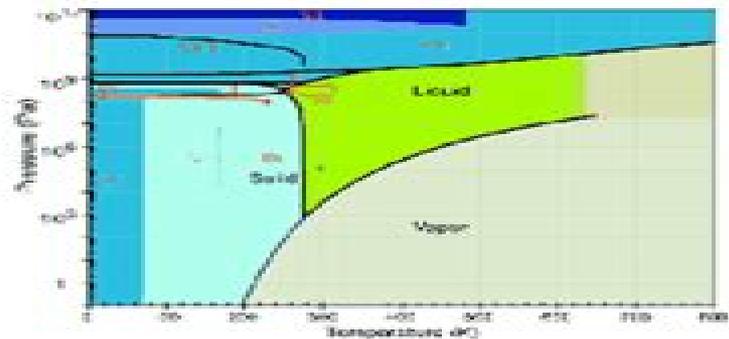


FIG. 1 The phase diagram of H_2O (Chaplin, 2007). Besides the liquid and gaseous phases a variety of crystalline and amorphous phases occur. Of special importance in the context of strongly interacting matter is the critical endpoint between the vapor and liquid phase.

have been identified. Famous points in the phase diagram are the triple point where the solid, liquid, and gas phases coexist and the critical endpoint at which there is no distinction between the liquid and gas phase. This is the endpoint of a line of first-order liquid-gas transitions; at this point the transition is of second order.

Under sufficient heating water and, for that matter any other substance, goes over into a new state, a 'plasma', consisting of ions and free electrons. This transition is mediated by molecular or atomic collisions. It is continuous¹ and hence not a phase transition in the strict thermodynamic sense. On the other hand, the

¹ Under certain conditions, there may also be a true plasma phase transition, for recent evidence see (Rortner et al., 2007).

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