A New Perspective on the Liquid-Vapor, Liquid-Solid, and Solid-Vapor Critical Points of Hydrogen

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The critical point concept, in classical thermodynamics, was first defined along temperature, pressure, and density (T_{cr}, P_{cr}, ρ_{cr}) values, which belong to the end of the liquid-vapor equilibrium curve [1,2] and were supported by Van der Waals' theory [3]. However, this classical approach asserts that only temperature reaches the critical value while pressure and density change depending on it. This study aims to reevaluate critical parameters of pure substances by going beyond the limits of classical approaches [4].

The results of analyses with the method of thermo-axiomatic geometry and high-pressure experiments on benzene and benzonitrile derivatives show that the liquid-vapor critical pressure is much higher than the classical value. For instance, the experimental critical pressure of benzene was determined as $\mathbf{P_{cr} \approx 2229}$ bar, and this state was explained by the system's transition to the metastable region [5]. This condition can not be explained with classical theories.

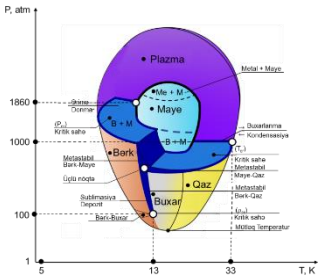

Figure 1 P-V-T Phase Diagram of Hydrogen

This study, at the same time, shows that the critical point concept is not limited to the liquid-vapor boundary curve, but also **liquid-solid** and **solid-vapor** transitions do have critical ending points [6]. Accordingly:

- At the end point of the liquid-vapor phase, the temperature,
- At the end of the liquid-solid boundary curve, the pressure,
- At the end of the solid-vapor boundary curve, the density is defined as a critical parameter.

With these, for a comprehensive understanding of phase transitions, a three-dimensional P-V-T phase diagram was created, and the plasma phase was also integrated into this structure as shown in Fig. 1. This new diagram, by going beyond two-dimensional P-T representations, facilitates multidimensional and topological analyses of energy systems, material technologies, and high-pressure environments. In this study, the determination of the critical pressure of hydrogen on the liquid-solid boundary curve and three-dimensional P-V-T phase diagram has been addressed [7].

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