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Thermodynamic Equilibrium, Nambu Brackets and Induced Hessians

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We introduce the notion of global and local thermodynamic equilibrium for any thermal system with well-defined first law. Our approach relies only on few key concepts, namely: Legendre transformation, Hessian matrices, Nambu brackets and thermodynamic curvature. In the extremal point, every convex (concave) potential must be in its global minimum (maximum). This allows one to impose standard conditions on the second derivatives (the elements of the Hessian) of the potential to fully determine the global equilibrium of the system. When turning to a different thermodynamic potential via a Legendre transformation, it may not be fully convex (concave) in its natural parameters. In this case, to translate the condition for global thermodynamic equilibrium, one must relate the components of the new Hessian to the previous one. The relation turns out to be a non-trivial mapping (a generalized pushforward/pullback) from one thermodynamic space to another involving curvature terms. We show that the components of the new induced Hessians can be equivalently calculated within the Nambu Bracket formalism. The latter is in the core description of the local thermodynamic equilibrium.

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