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Thermal operations from informational equilibrium

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Thermal operations are quantum channels that have taken a prominent role in deriving fundamental thermodynamic limitations in quantum systems. We show that these channels are uniquely characterized by a purely quantum information theoretic property: They admit a dilation into a unitary process that leaves the environment invariant when applied to the equilibrium state. In other words, they are the only channels that preserve equilibrium between system and environment. Extending this perspective, we explore an information theoretic idealization of heat bath behavior, by considering channels where the environment remains locally invariant for every initial state of the system. These are known as catalytic channels. We show that catalytic channels provide a refined hierarchy of Gibbs-preserving maps for fully-degenerate Hamiltonians, and are closely related to dual unitary quantum circuits.

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