H-Theorem in quantum physics

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Remarkable progress of quantum information theory (QIT) allowed to formulate mathematical theorems for conditions that data-transmitting or data-processing occurs with a non-negative entropy gain. However, relation of these results formulated in terms of entropy gain in quantum channels to temporal evolution of real physical systems is not thoroughly understood. Here we build on the mathematical formalism provided by QIT to formulate the quantum H-theorem in terms of physical observables. We discuss the manifestation of the second law of thermodynamics in quantum physics and uncover special situations where the second law can be violated. We demonstrate that the entropy of an energy-isolated system can be decreased for a specific system-environment interaction. This entropy-decreasing process is naturally expressed through the action of a quantum Maxwell demon and we propose a quantum-thermodynamic engine with four qubits that extracts work from a single heat reservoir when provided with a reservoir of pure qubits.