

Robust Catalysis and Resource Broadcasting: The Possible and the Impossible

In resource theories, catalysis refers to the possibility of enabling otherwise inaccessible quantum state transitions by providing the agent with an auxiliary system, under the condition that this auxiliary is returned to its initial state at the end of the protocol. Most studies to date have focused on fine-tuned catalytic processes that are highly sensitive to error: if the initial state of the system deviates even slightly from that for which the catalyst was designed, the catalyst would be irreparably degraded. To address this challenge, we introduce and study robust catalytic transformations and explore the extent of their capabilities. It turns out that robust catalysis is subtly related to the property of resource broadcasting. In particular, we show that the possibility of robust catalysis is equivalent to that of resource broadcasting in completely resource non-generating theories. This allows us to characterize a general class of resource theories that allow neither robust catalysis nor resource broadcasting, and another class where instead resource broadcasting and robust catalysis are possible and provide maximal advantage. Our approach encompasses a wide range of quantum resource theories, including entanglement, coherence, thermodynamics, magic, and imaginarity.