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Irreversible thermodynamics of transport and relaxation of magnetic moments with applications for spin caloritronics

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Spin caloritronics is mainly focused on studying the effects of a temperature gradient on the time evolution of the local spin average of a classical system. In many experimental situations, the system can be treated as a classical continuum with magnetisation on the scale of interest where the quantum fluctuations average out and the underlying microscopic structure is smoothed out. Here, we establish a clear classical formalism describing the thermodynamics of a matter continuum with magnetic moments interacting with external electromagnetic fields. Taking into account the chemical nature of the current densities – such as the current density of magnetic moments – and stress tensors leads to three types of dissipation terms: scalars, vectors and pseudo-vectors. The scalar terms account for the chemical reactivities, the vectorial terms account for the transport and pseudo-vectorial terms account for the relaxation. The vectorial phenomenological relations establish notably the Spin Seebeck effect first observed by Uchida and Saitoh. The pseudo-vectorial phenomenological relations establish in particular the Landau-Lifschitz relaxation of the magnetisation.