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Meyer-Neldel Rule on thermal stability parameters (trap depth and frequency factor) of luminescence signals in quartz

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Thermally activated processes can be described mathematically by the Arrhenius equation. The Meyer-Neldel Rule (MNR), or compensation law, linearly relates the pre-exponent term to the logarithm of the excitation enthalpy for processes that are thermally driven in an Arrhenian manner. This empirical rule was observed in many areas of materials science, in physics, chemistry, and biology. In geosciences it was found to uphold in hydrogen diffusion (Jones 2014a) and proton conduction (Jones 2014b) in minerals.

Trapped charge dating methods that use electron spin resonance (ESR) or optically or thermally stimulated luminescence (OSL and TL) are based on the dose-dependent accumulation of defects in minerals such as quartz and feldspar. The thermal stability of these defects in the age range investigated is a major prerequisite for accurate dating, while the accurate determination of the values of the trap depths and frequency factors play a major role in thermochronometry applications.

The correlation of kinetic parameters for diffusion has been very recently established for irradiated oxides (Kotomin et al. 2018). A correlation between the activation energy and the frequency factor that satisfied the Meyer–Neldel rule was reported when the thermal stability of $[AlO_4/h^+]^0$ and $[TiO_4/M^+]^0$ ESR signals in quartz was studied as function of dose (Benzid and Timar-Gabor 2020). Here we compiled the optically stimulated luminescence (OSL) data published so far in this regard, and investigated experimentally the thermal stability of OSL signals for doses ranging from 10 to 10000 Gy in sedimentary quartz samples. We report a linear relationship between the natural logarithm of the preexponent term (the frequency factor) and the activation energy E, corresponding to a Meyer-Neldel energy of 45 meV, and a deviation from first order kinetics in the high dose range accompanied by an apparent decrease in thermal stability. The implications of these observations and the atomic and physical mechanisms are currently studied.

References

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