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Barium and europium abundances in cool dwarf stars and nucleosynthesis of heavy elements

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Abstract

We revise barium abundances in 29 cool stars with metallicities [Fe/H] ranging from -2.20 to 0.07 and europium abundances in 15 stars with [Fe/H] from -1.52 to 0.07. The sample has been extracted from Fuhrmann's lists (1998, 2000) and confined to main-sequence and turnoff stars with only one subgiant added. The results are based on differential NLTE model atmosphere analyses of spectra that have a typical S/N of 200 and a resolution of 40000 or 60000. The statistical equilibrium of Eu II is first investigated with a model atom containing 32 levels of Eu II plus the ground state of Eu III. NLTE effects decrease the equivalent widths of the Eu II lines compared with LTE resulting in positive NLTE abundance corrections which are below 0.08 dex for all the stars investigated. The solar barium abundance loge εBa⊙ = 2.21 and the europium abundance log εEu,⊙ = 0.53 are found from the Ba II and Eu II solar flux line profile fitting, and they coincide within error bars with meteoritic abundances of Grevesse et al. (1996). Here the usual scale with log εH = 12 is used. The isotopic ratio 151Eu: 153Eu = 55: 45 is obtained from solar disk center intensity profile fitting of the Eu II λ4129 Å line. We report here for the first time that the elemental ratios [Ba/Fe], [Eu/Fe] and [Eu/Ba] show a different behaviour for stars of different Galactic populations. For the halo stars the [Ba/Fe] ratios are approximately solar, europium is overabundant relative to iron and barium with the mean values [Eu/Fe] = 0.62 and [Eu/Ba] = 0.64. For thick disk stars it is found that a) barium is slightly underabundant relative to iron by about 0.1 dex; b) europium is overabundant relative to iron with the [Eu/Fe] ratios between 0.30 and 0.44; and c) europium is overabundant relative to barium with a mean value of [Eu/Ba] = 0.49 ± 0.03. A step-like change in the [Eu/Ba] and [Ba/Fe] ratios occurs at the thick to thin disk transition; so, nearly solar elemental ratios [Ba/Fe], [Eu/Fe] and [Eu/Ba] are found for the thin disk stars. These data suggest that a) the halo and thick disk stellar population formed quickly during an interval comparable with the evolution time of an AGB progenitor of 3 to 4 M⊙, and the r-process dominated heavy element production at that epoch; b) there was a hiatus in star formation before the early stage of the thin disk developed. The even-to-odd Ba isotope ratios estimated from hyperfine structure (HFS) affecting the Ba II resonance line in the halo and thick disk stars favour a significant contribution of 138Ba to barium for a pure r-process, and this is supported by the recent data of Arlandini et al. (1999).

Keywords

Galaxy: evolution, Line: formation, Nuclear reactions, nucleosynthesis, abundances, Stars: abundances, Stars: late-type, Sun: abundances