SOLAR ISOTOPIC COMPOSITION AND ABUNDANCE OF EUROPIUM

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Abstract. High resolution spectra of six photospheric Eu II lines have been studied using the method of spectrum synthesizing. The isotope ratio is found to be Eu_{153}/Eu_{151} = (48 ± 6)/(52 ± 6) and the solar abundance of europium equals log_e Eu = 0.7 ± 0.2 in the log_e H = 12.00 scale.

1. Introduction

The solar abundance of europium has earlier been investigated by several authors: Grevesse and Blanquet (1969) derived the value log_e Eu = 0.49 ± 0.14 (in the log_e H = 12.00 scale), Wallerstein (1966) fixed the abundance at 0.8, while Righini and Rigutti (1966) and Bachmann et al. (1970) found values of 0.96 and 1.0 respectively.

From a study of the photospheric spectrum of the Eu II line at 4129 Å Grevesse and Blanquet (1969) derived an abundance of log_e Eu = 1.12. This figure is about 0.6 dex higher than the values obtained by the same authors from other Eu II lines and they concluded that the 4129 Å line must be blended. This line was therefore omitted in the isotope investigation undertaken by Hauge (1970). Later, Bachmann et al. (1970) studied the 4129 Å wavelength region using photospheric and sunspot spectra. In both cases an abundance of log_e Eu = 1.0 was obtained. This, together with other evidence led the authors to conclude that the Eu II line is unblended. The europium abundance given by Bachmann et al. (1970) was derived from this Eu II line only.

The Eu II line at 4129 Å, provided it is unblended, very favourable for isotopic investigations. Therefore this line, together with the five other Eu II lines previously investigated by Hauge (1970), have been reexamined using high resolution spectra.

Europium has two stable isotopes: Eu_{151} and Eu_{153}. The terrestrial isotope ratio is: Eu_{153}/Eu_{151} = 52.2/47.8 (or as given in a logarithmic scale: log_e(Eu_{153}/Eu_{151}) = 0.04). As the two isotopes are present in almost the same concentration and have different hyperfine broadening, europium is favourable for isotopic investigations.

2. Observations and Method of Analysis

More detailed descriptions of the observations and the method of analysis were recently given by Hauge (1972a, b).

The six Eu II wavelength regions were observed by the author with the McMath Solar Telescope at Kitt Peak National Observatory during the spring of 1971. Each spectrum is an average of 100 consecutive scans, and the spectral resolution is about
7 mA. All regions were observed with the spectrograph slit placed at the centre of the solar disk and at a position near the limb corresponding to μ = 0.3.

The analysis has been carried out using the method of spectrum synthesizing. The resulting intensity of various lines and hyperfine components are obtained by numerical integration of the contribution from each component of the blend through the model atmosphere.

The atmospheric model given by Holweger (1967) has been used. As demonstrated by Hauge (1972a), isotope investigations are not sensitive to the choice of atmospheric model. The macro- and microturbulent velocities were determined by fitting synthetic profiles to unblended lines occurring on the same records as the europium lines. No isotope shift or hyperfine broadening was expected to be present in the unblended lines which were selected. Best fit to the observed profile from the centre of the solar disk was obtained by neglecting macroturbulence and by assuming the following behaviour of the microturbulent velocity as a function of optical depth: 1 km s⁻¹ above log τ = −2.3, 2.9 km s⁻¹ below log τ = 0.3 and a linear function of log τ in the interval between. This velocity distribution is in agreement with recent results from the 7000 Å region reported by Hauge (1972b).

The partition functions of europium were taken from Corliss and Bozman (1962).

3. Spectroscopic Data

Laboratory data on the six Eu II lines have been published by Krebs and Winkler (1960). The transitions are between levels having quantum numbers J equal to 3 or 4. For both europium isotopes the nuclear angular momentum quantum number I equals \( \frac{5}{2} \). The number of hyperfine levels in each state is therefore equal to 6. The hyperfine splitting in the lower \( ^7S_3 \) and \( ^9S_4 \) states are considerably larger than in the upper ones. Then, transitions between a lower hyperfine level with quantum number \( F \) and upper levels having quantum numbers \( F-1, F \) and \( F+1 \) give three hyperfine components at rather closely spaced wavelengths. In the present investigation the intensities of these three components are added. The hyperfine structure is considered to consist of 6 main components. The intensity ratio between these components is calculated to be 6:5:4:3:2:1 for the Eu II lines at 3930, 3972 and 4435 Å. The ratio is 7:6:5:4:3:2 for the lines at 3725, 4129 and 4205 Å. A more detailed description of the hyperfine structure including intensity distributions was recently given by Hauge (1972c).

The energy differences between the hyperfine levels of Eu₁₅₁ are approximately 2.25 times the corresponding differences in Eu₁₅₃. Eu₁₅₁ has a total hyperfine splitting ranging from 140–238 mA for the six lines investigated.

4. Spectral Line Investigations

A. THE ISOTOPE RATIO DETERMINED FROM FOUR Eu II LINES

The four spectral lines listed in Table I were previously examined by Hauge (1970). The analysis was performed using spectra recorded on photographic emulsion and