Thorium in the spectrum of HR465

THE peculiar A star HR465 is a spectrum variable[1]. Considerable attention[2,3] has been given to the spectra of this star obtained by W. P. Bidelman during 1960–61, when the lines of the rare earth elements attained their maximum intensity; Bidelman has kindly placed this material at our disposal. Among the remarkable aspects of the HR465 spectrum is the fact that it is the only star for which a firm statistical basis exists for the identification of uranium[4].

Bidelman (unpublished) has assigned a moderate spectral feature in HR465 at λ4019.12 to Th II λ4019.13, which is the strongest accessible thorium line. The occurrence of this line in stellar spectra is very unusual. We base this statement on an extensive series of wavelength measurements made by C.R.C. and G.C.L.A. on 2.4 Å mm^{-1} plates taken at the Dominion Astrophysical Observatory. Combining these results with previous work[2,5], we have measured wavelengths in some 50 Ap and Am spectra, many of them very rich and sharp-lined, and only HR465 shows a line within 0.04 Å of λ4019.13.

The thorium identification can be based on more than the single line λ4019. We have re-examined the statistics of wavelength coincidences using the Th II wavelengths and intensities given by Meggers, Corliss and Scribner[6]. Coincidences within ± 0.04 of stellar wavelength with Th II are significant at the 95% confidence level or higher. The highest significance (99.5% confidence) was based on four coincidences within ± 0.02 Å using a list of seven Th II lines with laboratory intensities greater than 1,000. These results are somewhat more favourable than those obtained earlier[2].

We have obtained an abundance for thorium in HR465 at rare-earth maximum from this line using the method of Cowley and Hartoog[4]. The gf values were taken from Corliss and Bozman[7] or computed from the data in Meggers *et al.*[6] using atomic data supplied by Corliss.

This method shows a remarkable consistency. For example, we determined the thorium–neodymium abundance ratio using λ4018.69 of Nd II, and the thorium–gadolinium ratio using λ4013.80 of Gd II. When these ratios were converted to absolute abundances using Aller's[1] analysis of HR465, the results are within 0.2 in the logarithm. Other abundance determinations[8] show a similar self consistency.

The absolute abundance that we derive for Th is 4.4 ($\log H = 12.0$). This should be compared with the uranium abundance of 4.6, which we now revise from ref. 4 on the basis of a new second ionisation energy for uranium[9]. We believe this result to be correct to slightly better than an order of magnitude.

If we assume that the present Th–U ratio of -0.2 dex ($\pm$roughly 0.7 dex) in HR465 is the result of radioactive decay following the nucleosynthetic event, then we can say that the event must have taken place more recently than the time of the birth of the Galaxy, some 10^{10} or more years ago.

Certain non-nuclear[10,11] theories of the origin of abundance anomalies in Ap stars would obfuscate any conclusion of this kind. But these theories have not been developed to the point where they can make definite prediction of the relative abundances of heavy nuclides. On the other hand, it has been shown[8] that the relative abundance pattern of the heavy nuclides in HR465 resembles the prediction of the r-process. We shall, therefore, proceed with a nuclear interpretation, which at present provides the most complete and detailed basis for an understanding of the observations.

Cameron[12] gives 0.67 for the logarithm of the solar system thorium–uranium ratio. Our result differs from this by 0.87 in the logarithm. If these figures could be taken at their face value, there would be a clear indication from the work of Blake and Schramm[13] that the HR465 material was processed less than 10^9 yr ago while the Solar System r-process ceased more than 10^9 yr ago. Unfortunately, the uncertainty of the present determination will not permit this interesting conclusion, and we must content ourselves with the statement that thorium and uranium were made in HR465 at some time more recently than the formation of the oldest globular clusters.

The significance of this crude cosmochronological result lies in the fact that it depends on observations of an object outside of the Solar System.

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Received July 1; accepted August 15, 1975.

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Controlled artificial generation of geomagnetic pulsations

THERE has been a shift away from purely passive studies of the ionosphere and magnetosphere to more active studies in which the response of these regions to a controlled man-made disturbance is determined by experiment[1,2]. One area of research where active experiments may be particularly useful is in the study of ultra low frequency (u.l.f.) waves in the ionosphere and magnetosphere. We do not yet completely understand these waves from observations of the geomagnetic pulsations they produce because of the great difficulty in separating source and propagation effects. This problem is particularly acute for the u.l.f. waves generating Pc 1 geomagnetic pulsations (0.2–5 Hz) where the wavelengths are small compared with the dimensions of the magnetosphere. What is needed is a controlled

Fig. 1 Large scale representation of the island/circular sea model. The island is connected to the shore of the sea by a narrow insulating neck of length 100 m at the point of closest approach. Other relevant dimensions are: island radius 10 km, sea radius 100 km, sea depth 50 m, total current between electrodes on either side of the neck 3,000 A. Two of the circular current flow lines in the sea are indicated by arrows.