

Lounasmaa [10] yield a mean value of  $138 \times 10^{-4}$  for his samples I and II. The amounts of  $\alpha$  and  $\beta$ -Ce present in the first two investigators' samples were not known and were estimated on the basis of the results of Gschneidner, *et al.* [37]. From X-ray measurements Lounasmaa, however, did give estimates of the amounts of  $\alpha$  and  $\beta$ -Ce present in his sample, and therefore, we feel that his value for the electronic constant of  $\alpha$ -Ce is the best available. By using Eqn. (3) a value of  $\gamma = 138 \times 10^{-4}$  yields a density of states of 12.2 states/eV/atom at the Fermi level of the 1/3 filled 4f one-electron band of  $\alpha$ -Ce. It is assumed since the band is only 1/3 filled that the top of this band is greater than 12.2.

Although there is a large variation in the  $\gamma$  values estimated in the above manner, the important thing is that they are all extremely large. This variation may be due, not only to the approximations involved in estimating the quantities of  $\alpha$  and  $\beta$ -Ce in the samples, but also to impurities which will change the electron concentration and thus the Fermi level. Any small change in the Fermi level would be expected to cause a large change in the density of states because of the narrowness of the 4f band.

With such a narrow band the high density of states of  $\alpha$ -Ce should be very sensitive to temperature and to impurities. Indeed by using the method of Mott [42], the degeneracy temperature of this band is calculated to be 116°K. Alloying studies would be very revealing if one could prevent the  $\beta$ -Ce from forming upon cooling. Indeed it would be desirable if one could obtain pure  $\alpha$ -Ce to measure the physical properties of it at low temperatures.

When  $\gamma$ -Ce transforms to  $\alpha$ -Ce it not only undergoes a large volume contraction, but also a large decrease in the electrical resistivity (from 70  $\mu$  ohm-cm to 30  $\mu$  ohm-cm). This decrease in resistivity can be crudely accounted for by the increase in the number of conduction electrons (by about 2/3 of an electron per atom) and the decrease in the number of 4f electrons (by about 2/3 of an electron per atom), which give rise to the magnetic contribution to the resistivity. Interband scattering (s-f and d-f) would be expected to cause

an increase in the resistivity of  $\alpha$ -Ce (this contribution is zero in  $\gamma$ -Ce because the 4f level is essentially filled). We can roughly estimate the decrease in the resistivity of the first two contributions mentioned above. The resistivity of the tetravalent metals titanium, zirconium, hafnium and thorium range from 18 to 43  $\mu$  ohm-cm. [43] Assuming a mean value of 60  $\mu$  ohm-cm for a normal trivalent rare earth metal with no 4f electrons\*, and a mean value of 30  $\mu$  ohm-cm for the tetravalent metals, we would expect a decrease in resistivity of 30  $\mu$  ohm-cm for a metal which has undergone a valence change from three to four. The magnetic contribution to resistivity of a metal with one 4f electron is about 6  $\mu$  ohm-cm [44]. Since in the case of the cerium transformation about 2/3 of the 4f electron goes into the 5d 6s band, we would expect a resistivity decrease of about 25  $\mu$  ohm-cm (2/3 times 30 + 6). This is somewhat smaller than the 40  $\mu$  ohm-cm change observed, but it is still about the right order of magnitude to account for this change considering the approximations made. From this it would appear that the s-f and d-f interband scattering contribution to the resistivity is quite low and perhaps negligible.

It should be noted that Rocher's virtual 4f bound state model [29] appears to apply to  $\alpha$ -Ce, and it may be considered to be an alternate approach to the understanding of the behavior of this phase.

## 8. BAND STRUCTURE OF EUROPIUM AND YTTERBIUM

### 8.1 EUROPIUM

Europium has only two valence electrons available. These two electrons could easily fill the 6s band, and if there were no overlapping 5d band europium would either be a semiconductor or an insulator and the density of states would be zero.

---

\* Resistivities of scandium, yttrium and lanthanum vary from 57 to 67  $\mu$  ohm-cm.