compound having the hexagonal C32 structure. The Ce atoms are in layers normal to the *c* axis. In one layer, those Ce atoms in alternate rows parallel to *b* are moved slightly in the $+a^*$ direction. In the other rows the Ce atoms are moved in the $-a^*$ direction. In the next layer above, these movements are reversed. The Cu atoms are then moved in the *c* direction to relieve the strain produced by the Ce atom movement. These small movements change the symmetry to *Imma* and the two cells are related by the transformation

$$\begin{aligned} \mathbf{A} &= \mathbf{a} \\ \mathbf{B} &= 2\mathbf{c} \\ \mathbf{C} &= \mathbf{a}-2\mathbf{b} \end{aligned}$$

where **A**, **B** and **C** refer to the orthorhombic cell and **a**, **b** and **c** to the hexagonal C32 cell.

Each Ce atom has four Ce neighbors in a distorted tetrahedron and twelve Cu neighbors in two distorted hexagons, one hexagon on each side of the Ce atom. Two Ce atoms are pushed in between these hexagons of Cu atoms so that the hexagons are separated from each other more on one side than the other.

Each Cu atom has six Ce neighbors and four Cu neighbors. The Ce atoms are arranged in a trigonal prism but the atoms at one end of the prism are spread apart somewhat. There are three Cu neighbors co-planar with the central Cu atom and the fourth Cu neighbor is displaced outward from the center of the larger end of the trigonal prism of Ce neighbors.

References

Cromer, D. T., Larson, A. C. & Roof, R. B. (1960). *Acta Cryst.* **13**, 913.

Forsyth, J. B. & Wells, M. (1959). *Acta Cryst.* **12**, 412.

Waser, J. (1951). *Rev. Sci. Instrum.* **22**, 563.

Acta Cryst. (1961). **14**, 74

The β-Ag$_3$In phase.

By D. P. Morris and I. Williams, *Physics Department, University College of North Wales, Bangor, Great Britain*

(*Received* 6 *January* 1960)

It is well-known that a body-centred cubic 3:2 electron compound, usually called the β-phase, occurs in binary alloys of copper with aluminium, indium, gallium, and tin, and of silver with aluminium and indium. The factors affecting their formation have been fully discussed by Hume-Rothery *et al.* (1940*a*). The structures are stable only at high temperature and decompose in a complex way on quenching. The lattice parameters of these phases are all known except for β-Ag$_3$In, where the only high-temperature X-ray investigations (Hume-Rothery *et al.*, 1940*b*) appear to have been confined to the $(\alpha+\beta)$ region.

In connection with recent work on silver-based Heusler alloys (Morris *et al.*, 1959), we have had occasion to examine the β-Ag$_3$In phase. According to the phase diagram published in *Structure Reports*, **11**, 1947–8, the β-phase extends over a narrow range of composition around 25 at.% In and between temperature limits 660 to 693 °C. The alloy investigated was made from spectroscopically standardized silver and indium to the exact composition Ag$_3$In, the weight loss on melting the elements in an evacuated silica tube being negligible. High-temperature X-ray photographs confirmed that the β-phase structure was body-centred cubic, and the absence of extra reflections showed that the alloy was single-phase at 684 °C., with $a=3{\cdot}3682$ Å. Wavelengths were taken from Lonsdale (1950). The lattice parameters of all the β-phases of the copper and silver alloys are set out below (Pearson, 1958). The factor ($\times 1{\cdot}00202$) was used to convert kX. units to Å.

β-Ag$_3$Al 3·302 Å at 700 °C.
β-Ag$_3$In 3·3682 Å at 684 °C.
β-Cu$_3$Al 2·9564 Å at 672 °C. at $\alpha/(\alpha+\beta)$ boundary
β-Cu$_4$In 3·0461 Å at 672 °C. at $\alpha/(\alpha+\beta)$ boundary
β-Cu$_3$Ga 2·9671 Å at 672 °C. at $\alpha/(\alpha+\beta)$ boundary
β-Cu$_5$Sn 3·0200 Å at 672 °C. at $\alpha/(\alpha+\beta)$ boundary

Addition of manganese to the β-phases of the copper alloys permits the high-temperature structures to be retained by quenching, and also leads to the development of order, until ultimately at compositions Cu$_2$Mn*X* the alloys have the Heusler structure and are ferromagnetic. It has been shown however (Morris *et al.*, 1959) that no Heusler structure exists at either Ag$_2$MnAl or Ag$_2$MnIn, and Hall (1959) has established that the β-Ag$_3$Al phase is not stabilized by addition of manganese and that the high-temperature β-phase does not extend to the composition Ag$_2$MAl. In both Ag–Mn–Al and Ag–Mn–In the extension of the β-phase into the ternary system is thus considerably less than in the corresponding copper series. Since the magnetic properties of the Heusler alloys suggest that the manganese atoms are univalent, this difference in behaviour may be attributed to size-factor effects, substitution of copper by manganese in the β-phases being favoured by their similar atomic diameters, but not substitution of silver by manganese.

The authors wish to acknowledge their gratitude to the Council of the Royal Society for a Grant-in-Aid.

References

Hall, E. O. (1959). *Phil. Mag.* **42**, 730.

Hume-Rothery, W., Reynolds, P. W. & Raynor, G.V. (1940*a*). *J. Inst. Metals*, **66**, 191.

Hume-Rothery, W., Reynolds, P. W. & Raynor, G.V. (1940*b*). *J. Inst. Metals*, **66**, 209.

Lonsdale, K. (1950). *Acta Cryst.* **3**, 400.

Morris, D. P., Preston, R. R. & Williams, I. (1959). *Proc. Phys. Soc.* **73**, 520.

Pearson, W. B. (1958). *Handbook of Lattice Spacings and Structure of Metals*. London: Pergamon Press.