incipient crack. Thus $Z \sim 10w$, giving $T \sim 10w/b\epsilon$. If we insert as typical values, $w = 10^{-4}$ cm., $b = 5 \times 10^{-7}$ cm. (corresponding to the passage of a group of about 20 dislocations at each slip), and $\epsilon = 10^{-3}$, we get for T about 2×10^6 cycles. The first incipient cracks will appear at about 1.3×10^5 cycles. The satisfactory agreement with the order of magnitude found in practice for life-times suggests that it would be worth while to investigate a more realistic model of this type.

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² Mott, N. F., *Acta Metallurgica*, 6, 195 (1958).

Oxidation of Titanium-Iron Alloys

ABOVE the transition temperature, the oxidation of titanium proceeds by a layer of titanium oxide (TiO_2) growing outwards by the migration of anion vacancies. Concurrently, a solid solution layer of alpha-titanium containing dissolved oxygen grows inwards. The alpha-layer is fairly uniform in thickness over the surface of the specimen. Micro-hardness measurements show a very marked hardness gradient across it, indicating an oxygen concentration gradient and suggesting that the rate of growth of the alpha-layer is controlled by the diffusion inwards of interstitial oxygen.

It has been found that the addition of small amounts of iron to titanium, while not markedly affecting the overall rate, modifies the structure of the alpha-layer. Alpha-plates form rapidly along some of the beta grain boundaries, plates about 0.5 mm. long forming in about 15 min. at 875°C. Later, the alpha-plates thicken slowly, and a two-phase alpha/beta layer of roughly uniform thickness is formed around the specimen and grows inwards. There is no hardness gradient within the alpha-

plates, suggesting that oxygen diffusion is not the controlling step in their formation.

However, when a specimen containing 3 per cent iron is quenched after oxidation, only the beta-phase remote from the alpha-plates is transformed martensitically, as is shown in Fig. 1. Duwez¹ has shown that above 4 per cent iron the martensite start temperature is less than room temperature and beta-phase is retained. From this it is deduced that the iron content in the beta-phase adjacent to the alpha-plates is greater than 4 per cent. Alpha titanium does not dissolve iron to an appreciable extent² and it would appear that the iron ejected from the advancing alpha-plates raises the concentration of iron significantly. It is not possible to determine the variations in the iron content of the beta-phase by micro-hardness measurements, because in the neighbourhood of 4 per cent iron the hardness of quenched titanium varies very little with iron content³. The oxygen content, as indicated by the hardness of the alpha-phase⁴, is about 2 per cent by weight at 850°C. and 2.5-3 at 900°C. which, if local equilibrium is assumed, indicates an iron content of about 6-7 per cent by weight⁵.

It is concluded, therefore, that there is an iron gradient in the beta-phase from the original 3 per cent at the centre of the grains remote from the alpha-plates to about 6 per cent by weight at an alpha/beta interface. The rate of thickening of the alpha-plates, and the rate of thickening of the alpha/beta two-phase layer at the specimen surface, are apparently determined by the rate of diffusion of iron away from the interface.

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³ Worner, A. W., *J. Inst. Met.*, 80, 213 (1951).

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⁵ Allen, N. P., Schofield, T. H., and Mellish, B., *J. Inst. Met.*, 82, 536 (1953).

Fig. 1 Titanium-3 per cent iron oxidized 90 min. at 860°C. ($\times 80$)

RADIOCHEMISTRY

Preparation of Radiochemically Pure Tritium Nuclear-labelled Morphine

MORPHINE has been labelled with carbon-14 in the N-methyl position by chemical synthesis^{1,2} and randomly by biosynthesis^{3,4}. Because of the metabolic lability of the N-methyl group and the need for considerable quantities of a product of high specific activity, studies on the preparation of tritium-nuclear labelled morphine were initiated. The Wilzbach procedure⁵ of exposure to tritium gas was utilized for the introduction of the tracer element into the morphine molecule. The preparation of biologically stable tritium-labelled morphine by this technique had been described previously⁶, and the radiochemical purity of the product was reported. We have found, however, that the exposure to tritium gas of morphine base or morphine sulphate in finely divided form, and subsequent purification to remove the labile tritium and radio-decomposition products, uniformly gave a seemingly pure crystalline morphine which showed two distinct areas of radioactivity when paper chromatograms were developed using correctly buffered paper