Self-Diffusion in Copper

Experiments have been made on the rate of self-diffusion in copper by using as indicator the radioactive isotope Cu^{64} (half-life 12.8 hours).[1] The experiments were made by bombarding the face of a cylindrical block of copper with 8 Mev deuterons in the cyclotron. In this way an active layer extending to a depth of about one-tenth of a millimeter was obtained. The copper cylinder was heated in a quartz tube in a furnace (usually for about 40 hours) and the penetration of the active copper into the block was then investigated by cutting successive sections from the specimen and measuring their activities. Since a deuteron bombardment of only three microampere-hours is sufficient to give an activity of about one millicurie, the activities could be easily measured with an electroscope at the conclusion of the heating period. The only other appreciable activity produced by the bombardment is that due to Cu^{66} which decays rapidly (six-minute half-life). There is a small uniform activity throughout the specimen due to activation by neutrons produced in other transformations during the bombardment but this is negligible compared with the deuteron activation. This method of activation has the advantage of simplicity and avoids any possibility of the existence of a boundary disturbance between the active layer and the bulk of the copper. In calculating the diffusion coefficient it is necessary to know the initial distribution of activity in the specimen which can be easily determined by experiment. The results for the distribution of activity after heating were found to be in good agreement with the appropriate solution of the diffusion equation:

$$\partial c/\partial t = D(\partial^2 c/\partial x^2).$$

From the preliminary experiments the following values of the diffusion coefficient have been obtained:

At 1030°C $D = 2.8\ 10^{-9}$ cm²/sec.
At 940°C $D = 3.5\ 10^{-10}$ cm²/sec.

A rough measurement at 830°C gave: $D = 4.10^{-11}$ cm²/sec.

These results are sufficient to show that the coefficient is smaller than that predicted by Rhines and Mehl[2] from the rates of diffusion in copper of aluminum, beryllium, cadmium, silicon, tin and zinc alloyed with copper. The activation energy Q for the diffusion process ($D = Ae^{-Q/RT}$) seems to be of the order of 60,000 cal./mole. The measurements are being continued and a full account will be published later.

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B. V. ROLLIN

Department of Chemistry,
Radiation Laboratory, Department of Physics,
University of California,
Berkeley, California,
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[1] S. N. Van Voorhis, Phys. Rev. **49**, 876 (1936).
[2] J. B. Rhines and R. F. Mehl, Metals Technology, **5**, Jan. (1938).