tative interpretations supported. (4) The Fermi surface of In may not resemble the free electron model as closely as had been previously thought, possibly having holes in the first zone and no electrons in the third zone.

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Coles: Mr. D. Farrell at Imperial College has found strong correlations between transition temperature and the occurrence of a Fermi-surface overlap in cp hexagonal phases based on zinc and cadmium.

Superconductivity in the Y–Rh and Y–Ir Systems

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We are trying to decide whether a critical condition for the occurrence of superconductivity exists or whether all nonferromagnetic metals will eventually become superconducting. By *eventually* we mean of sufficiently high purity and sufficiently low temperature. During the past five years it has become very likely that superconductivity seems to be the rule rather than the exception, and any critical condition may be purely theoretical. From symmetry considerations the transition temperatures of Sc, Y, and Rh will be rather low. As shown by Hamilton and Jensen[1] the superconducting temperatures of the transition elements are entirely symmetric with respect to the 6th column of the periodic system. Thus, Y will correspond to Rh and Sc to Co, if the latter were not ferromagnetic. La is a high-temperature superconductor *only* due to the vicinity of 4*f* levels and would otherwise correspond to Ir, a superconductor at 0.14°K. Since the 3rd and 9th columns are thus bracketing the range of high transition temperatures, one would now expect that most combinations of the 3rd with the 9th column would result in phases with transition temperatures higher than the elements in these columns. We have shown this to be so, thus strengthening our hypothesis as to the generality of superconductivity. The occurrence of superconductivity in the Y–Rh and the Y–Ir system is shown in Figs. 1 and 2. While the two systems are not isomorphous, between the two of them virtually the

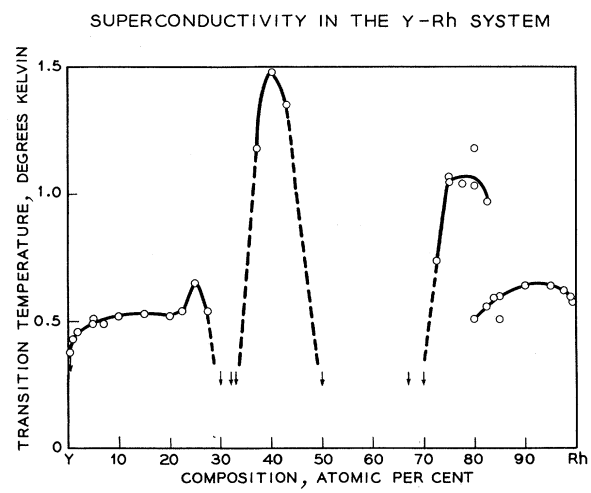

Fig. 1. Superconductivity in the Y–Rh system.

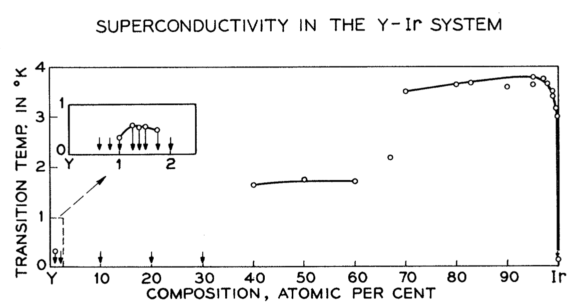

Fig. 2. Superconductivity in the Y–Ir system.

[1] D. C. Hamilton and M. Anthony Jensen, Phys. Rev. Letters, 11, 205 (1963).

whole range is covered with superconductors above 0.3°K. It is safe to assume that at lower temperatures than 0.3°K even more superconductors would be found.

It is interesting to note that at the very rhodium rich side the transition temperatures are about 5.5 times lower than in the very iridium rich phases. Since over 80% of these metals form the compounds one might try to draw conclusions as to the transition temperature of pure Rh. Should the same conversion factor be valid for the *pure* elements the transition temperature of rhodium would be near 25 mdeg.

Discussion 24

R. A. FERRELL, *University of Maryland:* Do you believe that sodium, if it is pure enough and cold enough, will be a superconductor?

MATTHIAS: Yes! I believe this but I don't know.

MENDELSSOHN: I fully understand the importance of straight belief—I just wonder whether you could give some indication of known miracles which would sustain your belief that things like pure sodium do become superconductive.

MATTHIAS: It is my belief in the religious significance of the 3rd law that it has to be so!

V. AMBEGAOKAR, *Cornell University:* I am afraid this discussion is becoming a little facetious but it should be said that, in an ideal Fermi gas, the entropy goes to zero at absolute zero so there is no contradiction with the 3rd law of thermodynamics. The question is whether you can get some other state for which the entropy increases more slowly than linearly with temperature. And you may very well do that.

MATTHIAS: Well as I pointed out in the beginning, the transition is either a superconducting or ferromagnetic or antiferromagnetic one or, speaking with Casimir, an insulator. This is all put forward quite clearly in the article of Casimir of last July at the Max Born festival in Z. Physik.

AMBEGAOKAR: May I just reiterate that the ideal Fermi gas and, which may be more relevant, the Landau–Fermi liquid, behave like metals and still have zero entropy at zero temperature.

MENDELSSOHN: There is an extension of the 3rd law which has always been believed and never proved. It is not only that zero entropy is approached, but how it is approached, and possible states with lower free energy could have a preference. That was the thing that sustains Matthias' belief; a superconductor contrary to the behavior of free Fermi gas approaches zero entropy more rapidly.

GORTER: Perhaps I may ask just why you think an antiferromagnetic cannot become superconductive.

MATTHIAS: You are right—I was wrong.

M. H. COHEN, *Institute for the Study of Metals:* I would like to place on record another brief prediction. Very pure sodium will not go superconductive at absolute zero.

MATTHIAS: Show me.

J. R. SCHRIEFFER, *University of Pennsylvania:* In support of Dr. Cohen's point of view, Mr. Wilkins has been calculating the transition temperature of a number of elements. In particular, he has calculated the transition temperature of Al and finds roughly 1.5°K. Now I don't claim this is a firm first-principles calculation, nor should one be very excited about the answer, but it was gratifying that the result turned out to be this order of magnitude. Now for sodium, one must be a bit careful to take into account the nature of the electron–phonon matrix elements for large momentum transfer. If one does a reasonably good job, as Wilkins has done, one finds that sodium is definitely not a superconductor in *s*-, *p*-, or *d*-state pairing.

MATTHIAS: Pure sodium of course has never been checked, since all sodium contains oxygen and sodium peroxide is paramagnetic with a finite Curie–Weiss constant. However you are quite right; there are all sorts of objections like the hyperfine splitting which may destroy superconductivity, but I just don't believe that nature is so complicated that some things are this, while others are nothing at all. I am convinced that there is a certain amount of order and I am sure order will be restored.