III. SOLID STATE PHYSICS

A. QUANTUM THEORY OF ANTIFERROMAGNETISM

The lowest energy state in the Ising model description of an antiferromagnetic substance is the one in which the maximum number of pairs of neighboring atoms have their electronic magnetic moments antiparallel. Neutron diffraction experiments [1] at low temperatures on antiferromagnetic crystals indicate that such ordered arrangements exist in nature.

A quantum mechanical treatment of the problem shows that, even in the nearest neighbor approximation, this completely alternating spin arrangement is not an exact eigenstate. We are trying to find the correct description of the lowest eigenstate and to relate this to the experimental picture.

We have investigated models with small numbers of spins exactly; for these, the completely alternating arrangement is not a very good approximation to the lowest eigenfunction. We are looking for methods of obtaining asymptotic results for large numbers; for these, the alternating arrangement might be a better approximation. (In approximate treatments of the infinite linear antiferromagnetic chain by Slater [2] and by Hulthen [3], the number of antiparallel pairs of neighbors in the lowest energy eigenstate deviates by about 12 percent, and 30 percent respectively, from the maximum possible.)

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References

(1) C. G. Shull, J. S. Smart: Phys. Rev. 76, 1256 (1949).
(2) J. C. Slater: Phys. Rev. 35, 509 (1930).
(3) Lamek Hulthen: Arkiv. f. Math., Astr. o. Fys. 26A (1938).

B. SOFT X-RAY VACUUM SPECTROGRAPH

The preliminary electron gun mentioned in the last Quarterly Progress Report turned out to be unsatisfactory. A new gun has been built which is considerably better than we had originally hoped for. It will put from 1 to 4 ma on the target for potential variations from 250 to 300 volts, with a total emission current of about 10 ma. The electron stream is deflected onto the target by means of an electric field, to avoid evaporation of the cathode material onto the target. The cathode itself is of a new molybdenum-thoria type as used in the high-power magnetrons and can be run at a very low temperature. This has helped to solve the problem of heat dissipation, which was a serious one, as well as greatly to reduce the evaporation of the cathode.

The final evaporation system for coating the target with the material under investigation has not yet been evolved. The present arrangement is not satisfactory.

In the spectrograph proper, the electron multiplier has been completed and tested. The counting circuits and amplifiers are operating satisfactorily; a counting rate meter circuit has been added to the output, capable of counting up to 10,000 counts/sec. Very recently some trial runs have been made with what was thought to be an aluminum coating on the target. The run was made with a 1-ma tube current at 250 volts, and slit widths of 0.003 in. on both source and detector. The results were rather discouraging, with a more or less uniform rate of 5000 counts/sec being observed over a wide range of angles. This turned out to be due largely to scattering from the zero-order light trap and from the masking strips in front of the grating. When these were removed a broad band was observed, of maximum height 5000 counts/sec, in the range from 50 to 80 ev (roughly). This is probably a superposition of the L_{23} band from aluminum and the M_{23} band from copper, since a later examination of the target showed that it was only partially coated.

Although these results are quite crude and unsatisfactory they do indicate that the apparatus is functioning. Improvements in the evaporating arrangement, and isolation of any remaining extraneous scattering should make it possible to carry out a final alignment of the grating and slit system, so that we can reasonably hope to have the equipment in operating condition before too long. Auxiliary work is getting under way to prove a high-vacuum spark source for calibration.

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C.   PARAMAGNETIC RESONANCE

Work has continued on construction and testing of new microwave and low-temperature apparatus. A helium cryostat has been set up and will be ready for test runs in the near future.

An apparatus is under construction by Dr. Malvano, a guest of the Laboratory, which involves a method of measurement different from that used for paramagnetic investigations in the past. The technique involves variation of the usual static magnetic field at 60 cycles in order to present the entire absorption pattern on the screen of an oscilloscope instead of taking point-by-point measurements. This method, which has been used by Dr. Malvano elsewhere, will probably turn out to be very useful in low-temperature measurements, where rapid data taking will be convenient and in some cases essential. It may be that the method will also allow new information to be obtained from the behavior of the resonance curves under the transient conditions imposed by the varying magnetic field.

The general program to be undertaken, outlined in the last Quarterly Progress

Report, will be somewhat expanded now that we have a larger group at work. We plan to extend the work beyond the simple resonance experiments in such directions as to improve our knowledge of paramagnetic properties, especially in the interesting region of low temperatures. Thus, if it turns out to be important, we may set up apparatus directly for measuring susceptibilities of crystals at low temperature. Combination of such measurements made by us or by others with anisotropy measurements obtained from resonance experiments should be very useful in improving our understanding of paramagnetism.

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D. THE THEORY OF THE TRANSPORT PHENOMENA IN METALS

A preliminary account of this work was presented in the last Quarterly Progress Report. The work has been completed and has been embodied in a paper which has been submitted for publication in the Proceedings of the Royal Society; it will also be issued as a technical report by this Laboratory. A summary of the paper appears below.

Exact expressions, valid for all temperatures, are obtained in the form of infinite determinants for the electrical conductivity, the thermal conductivity and the thermo-electric power of a degenerate gas of quasi-free electrons interacting with the ionic lattice of a metal. It is shown that the values of the electrical and thermal conductivities, in general, exceed the values given by the approximate interpolation formulae of Bloch (1), Wilson (2) and others, and, in particular, that the Grüneisen-Bloch formula for the ideal electrical resistance is appreciably in error in the region close to the Debye temperature. It is further shown that the residual and ideal resistances of an impure metal are not strictly additive in the region where the two are of the same order of magnitude. The behavior of the thermal conductivity is shown to agree qualitatively with the discussion based on Wilson's formula given by Makinson (3); the numerical values of the thermal conductivity are increased appreciably, particularly for an ideal metal at low temperatures. The thermoelectric power is also discussed, but no simple results can be given for the intermediate temperature range.

<div align="right">E. H. Sondheimer</div>

References

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(2) A. H. Wilson: Proc. Camb. Phil. Soc. $\underline{33}$, 371 (1937).

(3) R. E. B. Makinson: Proc. Camb. Phil. Soc. $\underline{34}$, 474 (1938).