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gas to the source while the accelerator is in operation. A PIG-type ion source is used (3), (4). Focussing is obtained by means of a single extraction electrode which operates as an *einzel* lens.

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* Supported in part by Canadian Atomic Energy Control Board.
[1] Paul Lorrain, Rev. Sci. Instr. **20**, 216 (1949).
[2] Edgar Everhart and Paul Lorrain, Rev. Sci. Instr. **24**, 221 (1953).
[3] Paul Lorrain, Can. J. Research **A25**, 338 (1947).
[4] Paul Lorrain, Helv. Phys. Acta **XII**, 497 (1948).

C5. Particle Selection Technique Used at the M.I.T. Cyclotron.* F. A. Aschenbrenner, *M.I.T.*—The particle selective counter consists of a thin plastic scintillation counter which measures dE/dx of the reaction particles and a NaI(Tl) counter which measures the remaining energy of the reaction particles after they pass through the thin counter. The product $E\cdot dE/dx$ which is proportional to the mass over a limited energy range is taken electronically and displayed on one axis of an oscilloscope. The energy is displayed on the other axis. The product and energy pulses are also sent through two pulse height analyzers. Output pulses from the analyzers actuate a coincidence circuit. The coincidence pulses trigger the intensity grid of the oscilloscope when the pulses on the two axes are at their maxima. Time exposure photographs of the oscilloscope show separate lines representing the resolved particles of different mass and also individual particle energy groups. The bias and gate of the product analyzer can then be adjusted so that only one type of particle is counted. The other analyzer can then be used to obtain the energy spectrum of the type of particle selected.

* This work has been supported in part by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

C6. Microtrons (Electron Cyclotrons for X and K Band Operation) II.[1] H. F. Kaiser, *Naval Research Laboratory.*—Three microtrons under study and development will be discussed: (1) a *K* band (24 Kmc) microtron which has been observed to operate in a low-energy mode; (2) a general purpose *X* band (9375 mc/sec) microtron which is being used to test microtron ideas and is suitable for electron and x-ray experimental research, including studies on extracted electron beams; (3) a high-power 1-megwatt *X* band microtron incorporating experience gained in design and operation of *X* band microtrons to-date. Development of the *K* band microtron depends at present on improvement of resonators and increase of available power, both of which are feasible. The *X* band microtron is easily operated with commercially available magnetrons and forms an easily operated and dependable accelerator for energies of several Mev.

[1] H. F. Kaiser, Phys. Rev. **91**, 456 (1953); J. Franklin Inst., Feb., 1954.

C7. Phase Properties of the Deflected Ion Beam from a Fixed-Frequency Cyclotron. M. Jakobson, *Montana State University,* and J. H. Manley, *University of Washington.*—The duration of the ion burst and the phase of the dee voltage as the deflected ion beam emerges from the University of Washington Cyclotron has been investigated. This knowledge is necessary for the measurement of reaction energies with a time of flight spectrometer. The ions were detected by means of a stilbene crystal mounted on a 1P21 photomultiplier. The photomultiplier signals were sent to the vertical amplifier of a 517 Tektronix. A rf pickup coil at the deflector provided the horizontal sweep and time base. The ions are sharply defined in phase at threshold. As the dee voltage is increased above threshold, and with the magnetic field tuned to resonance, the duration of the ion burst increases rapidly at first, then approaches a constant value. The ions emerge earlier in time as the magnetic field is *increased* through resonance. As different turns appear, a jump in time of arrival of the ions occurs. The phases of the emerging ions have been obtained by numerical integration and are in agreement with measurements.

C8. Betatron Orbit Stability as a Function of *n*. G. C. Baldwin, F. R. Elder, and W. F. Westendorp, *General Electric Research Laboratory.*—Experiments are in progress with a small betatron with symmetrical magnetic circuit and polepiece profile designed to produce a guide field exponent $n=0.7$ constant over a wide annular region. With low rate pulsed operation, n can be varied linearly from 0.5 to 0.9 by concentric polepiece windings excited by a current transformer. Reduced output and weak x-radiation throughout the acceleration cycle, indicating instability, are observed for discrete n values of 0.53, 0.56, 0.64, 0.75, >0.84. Theoretical analysis shows these to be the result of interaction with azimuthal guide field variations.[1]

[1] D. M. Denison and T. Berlin, Phys. Rev. **69**, 542 (1946); D. Judd, Ph.D. thesis, California Institute of Technology (1950).

C9. Spectral Distribution Curves of the Far Ultraviolet Radiation from the Cornell Synchrotron.* D. H. Tomboulian and P. L. Hartman, *Cornell University.*—Based on Schwinger's[1] theory, numerical calculations have been carried out for the purpose of comparison with recent[2] experimental observations of the electromagnetic radiation emitted by high-energy electrons. Tentative intensity distributions curves have been obtained from the spectrograms on the basis of certain assumptions regarding the distribution of energy among the different order spectra produced by the grating. Utilizing the narrow emission bands of certain light elements as the incident radiation, a determination of the actual grating response is in progress. More complete reduction of the experimental data must await the outcome of the current work on the efficiency of the grating.

* Supported by the Office of Ordnance Research, U. S. Army.
[1] J. S. Schwinger, Phys. Rev. **75**, 1912 (1949).
[2] P. L. Hartman and D. H. Tomboulian, Phys. Rev. **91**, 1577 (1953).

C10. A Gaseous Scintillation Counter. C. Eggler and C. M. Huddleston, *Argonne National Laboratory* (introduced by Louis A. Turner).—A photomultiplier tube has been used to measure the light emitted by argon and certain other gases when excited by α particles. A thin film of plastic color shifter has proved effective for converting spectral lines in the far ultraviolet into the region of photocathode sensitivity. Preliminary experiments, using a simple geometrical arrangement and a Pu source of known activity, indicate a counting efficiency approaching 100 percent. Pulse-height analysis strongly suggests the possibility of using a gaseous scintillation counter for heavy-particle spectral analysis.

C11. Measurement of the Time Jitter in BF_3 Counters. O. D. Simpson, *Phillips Petroleum Company.**—Time jitter or the variations in time delay after a neutron is absorbed until the α pulse is recorded has been measured for some commercial BF_3 counters. The gamma rays from the 470 kev level in Li^7 were detected by means of NaI crystal α photomultiplier and used to trigger an oscilloscope trace. By measuring the α-particle pulse number-time distribution, the time jitter was determined. A counter of 2-in. diameter, 60 cm of Hg BF_3, and 2-mil center wire showed variations of $2\frac{1}{2}$ μsec (the time between 50 percent of maximum probability values). A counter of 1-in. diameter, 65-cm Hg BF_3, and a 6-mil center wire showed variations of 0.5 ± 0.1 μsec. Factors involved in BF_3 counting characteristics are discussed with emphasis upon fast neutron chopper detectors.

* Work carried out under contract with the U. S. Atomic Energy Commission.

C12. Scintillation Detector for Thermal and Epithermal Neutrons. K. H. Sun, P. R. Malmberg, and F. A. Pecjak, *Westinghouse Research Laboratories.*—Thermal and epithermal

neutron detection by scintillation counters as compared with that by gas-filled counters has the advantages of simplicity, ruggedness, compact geometry, and better time resolution. Gamma insensitive neutron phosphors made from mixtures of boron-containing substances and ZnS−Ag have been investigated in great detail recently.[1–4] A phosphor of this type has been prepared from a glycerol borate plastic containing 20 weight percent boron mixed with du Pont 1410 (10 micron) ZnS−Ag. The low viscosity of the melted boron plastic at 200°C facilitates the thorough mixing with the ZnS−Ag which is essential to optimum counting efficiency and permits molding of the phosphor into any desired shape. Using disk-shaped phosphors and a Du Mont 6292 photomultiplier, optimum counting rates have been observed for a ZnS−Ag to boron plastic ratio of 2 and a thickness of about 1 mm. Estimated counting efficiencies for thermal neutrons greater than 10 percent have been attained using ordinary boron. A much greater efficiency is expected with enriched B^{10}.

[1] Palevsky, Muether, and Stolovy, Bull. Am. Phys. Soc. **28**, No. 6, 16 (1953).
[2] C. O. Muehlhause, BNL 242 (T-38). Also BNL 1953 Ann. Rep., p. 10.
[3] D. E. Alburger, BNL 1233.
[4] Gatti, Germagnoli, Persano, and Zimmer, Nuovo cimento (9), **9**, 1012–21 (1952).

C13. Vapor Expansion Chamber Using Pure Water. I. J. E. Hopson and C. E. Nielsen, *Ohio State University.*—A cloud chamber operating on pure water vapor has been built and operated. Provisions have been made for having a volume defined expansion of vapor, free from condensation nuclei and air, into a vacuum. Some important operating points are: a. by pumping on water it can be caused to supply vapor free of condensation nuclei. b. The chamber will hold a vacuum in the micron range thereby assuring the purity of the operating vapor. c. During expansion the vapor must not be in contact with a free liquid surface. d. After each expansion the entire system is pumped out and a new supply of vapor is used. Thus there are no reevaporation nuclei left in the chamber. e. The present chamber operates from an initial pressure of from one to two centimeters of mercury; thus, it is ideal for the study of low-energy ionizers. f. With suitable valves and vacuum pump the time interval between useful expansions can be less than 15 seconds. g. Clear alpha-particle tracks without background with a ratio of final to initial volumes of 1.7 with the initial temperature of the water at that of the room were observed.

C14. Vapor Expansion Chamber Using Ammonia and Water. II. R. P. Caren and C. E. Nielsen, *Ohio State University.*—The vapor expansion method of cloud-chamber operation in which after each expansion into an evacuated volume the chamber is refilled with clean vapor was tried with an ammonium hydroxide vapor source; good tracks were obtained. With this method of operation there is simultaneous cooling of the vapor in the chamber and heating of the vapor entering the expansion volume, and sensitive time characteristics approach those of Wilson chamber expansion to constant pressure. Expansion of the vapor in the chamber is less than in the Wilson chamber with the same ratio of final to initial volume, and the temperature ratio, given by $T_1/T_2=(V_2/V_1)^p$, is here found by using $p=(\gamma-1)/\gamma$. Pressure may be varied by varying the concentration of ammonia in the vapor source. In experiments involving stopping power the similarity of ammonia and water makes vapor composition relatively unimportant. This chamber is simple in construction, requires no clearing expansions, and may be operated at any desired pressure above the vapor pressure of water.

C15. Vapor Expansion Chamber Using Pure Gases at Low Temperatures. III. C. E. Nielsen and J. E. Hopson, *Ohio State University.*—A cloud chamber operated as described in the preceding abstracts has been cooled in liquid nitrogen and used with nitrogen vapor. With the ratio of final to initial volume constant, supersaturation obtained has been varied by varying the amount of undersaturation of the vapor before expansion. Ion tracks are observed from a minimum supersaturation of about two and one-half up to the maximum supersaturation of about five obtainable with the present apparatus. Uniform condensation on vapor aggregates is negligible in this range of supersaturation. Experiments with oxygen and argon are in progress; it is found that no condensation occurs in clean oxygen with supersaturations up to about six, the maximum yet studied. At these temperatures evaporation from the vapor source is so slow that an effective expansion is possible with a pool of liquid in the chamber. One could therefore use a Wilson chamber if it were desired. Droplets in nitrogen grow very rapidly, so that if tracks are to be photographed, the time delay between track formation and exposure must be made unusually short.

Thursday Morning at 10:00

Sheraton Park, Burgundy Room

(B. T. Matthias presiding)

Low-Temperature Physics

D1. The Effect of Temperature Scales on Low-Temperature Calorimetric Data. J. R. Clement, *Naval Research Laboratory.*—In correlating calorimetric and elastic data via Born-von Kármán theory, the Debye characteristic temperature for the lattice heat is usually the basis of comparison. For such correlations, a reliable estimate of the uncertainty in the absolute value of the caloric results is important. This fact has led to an investigation of the effect of uncertainties in the liquid helium vapor pressure-temperature scale on the absolute reliability of calorimetric data below 4.2°K. Certain apparent "anomalies" in some older data can be practically eliminated by correcting the data from the temperature scale in use at the time of the original experiments to the presently accepted (1949) scale. Furthermore, uncertainties in Debye temperatures deduced from data based on the 1949 scale have been considered in view of measured deviations from this scale.[1,2] For a hypothetical material having an electronic heat equal to the lattice heat at 10°K, an error in Debye temperature as large as 15 percent may occur around 1.5°K.

[1] J. Kistemaker, Physica **12**, 272 (1946).
[2] L. D. Roberts and R. A. Erickson, Phys. Rev. **91**, 488 (1953).

D2. Methods of Spinning Rotors at Low Temperatures.* J. W. Beams and J. B. Breazeale, *University of Virginia.*—Two methods of spinning rotors at high speeds at liquid helium temperatures are described. In the first method, the rotor is spun inside a tubular vacuum chamber on the end of a vertical small diameter, long, stainless steel hypodermic needle tube. The hypodermic needle shaft and rotor are driven and supported by an air-driven, air-supported turbine[1] located above the chamber. The chamber is sealed by a vacuum gland around the shaft. Vibrations in the long shaft are suppressed by properly spaced Teflon guides and special dampers. The rotor may be evacuated through the hollow shaft. In the second method the rotor is suspended inside a glass vacuum chamber by the axial magnetic field of a solenoid.[2] The solenoid is outside and coaxial with the Dewars containing the cooling liquids. The rotors are accelerated and driven around a vertical axis by a rotating magnetic field in a way similar to that of the armature of an induction or synchronous motor. The latter method is preferable if slight heating is to be avoided. In both methods the chambers surrounding the rotors are cooled by liquid helium surrounded by liquid nitrogen. Applications of the methods will be discussed.

* Supported by the Office of Ordnance Research.
[1] Beams, Revs. Modern Phys. **10**, 245 (1938).
[2] Beams, Young, and Moore, J. Appl. Phys. **17**, 886 (1947).

D3. The Magnetic Dependence of the Thermoelectric Power of Bismuth at Low Temperatures. J. Babiskin and M. C. Steele, *Naval Research Laboratory.*—Measurements have been made on the thermoelectric power of polycrystalline bismuth wire (0.020-in. diam, 10 in. long, 99.98 percent purity) against copper as a function of temperature and magnetic field at liquid helium temperatures. The lower junction was maintained at 4.2°K in liquid helium. The temperature of the upper junction (which was above the bath) ranged from 4.2°K to 10°K and was measured by a calibrated carbon thermometer. The thermoelectric power was found to vary from $6\mu v/°K$ at 5°K to $11\mu v/°K$ at 9°K in zero field. Upon applying a uniform longitudinal magnetic field of 70 gauss, the thermoelectric power increased ~ 10 percent. This is a much larger effect than that observed previously[1] at room temperature in stronger magnetic fields. Further increase of the field showed that thermoelectric power increased less rapidly and appeared to approach saturation at ~ 400 gauss, when the upper junction was at ~ 8°K. Preliminary measurements have also been made on a bismuth single crystal in transverse and longitudinal magnetic fields. While the thermoelectric power at zero field was somewhat higher than for the wire, fields up to 100 gauss produced much more pronounced effects than for the wire.

[1] C. W. Heaps, Phys. Rev. **31**, 648 (1928).

D4. The Temperature Variations of the Elastic Constants of Copper Single Crystals from 4.2°K to 300°K. John Gaffney and W. C. Overton, Jr., *Naval Research Laboratory.*—Using a previous developed cryogenic technique[1] together with an ultrasonic pulse technique, we have measured the adiabatic elastic constants of oriented single crystals of copper from 4.2°K to 300°K. The room temperature measurements are in excellent agreement with those of Lasarus,[2] while at 4.2°K the values of C_{11}, C_{12}, and C_{44} were found to exceed those at room temperature by 4.8 percent, 2.8 percent, and 8.6 percent, respectively. The experimental technique, measured crystal thickness corrections, and uncertainties of the elastic constants will be discussed. The Hooke's law atomic force constants for nearest and next-nearest neighbor interaction for the copper lattice have been obtained from these elastic constants by the relations $\alpha = ac_{44}$ and $\gamma = a(C_{11} - C_{12} - C_{44})/4$ where "a" is the lattice constant. The extrapolated value of γ/α at 0°K is -0.0946.

[1] W. C. Overton, Jr. and R. T. Swim, Phys. Rev. **84**, 758 (1951). W. C. Overton, Jr., thesis, Rice Institute, 1950.
[2] D. Lasarus, Phys. Rev. **76**, 545 (1949).

D5. Correlation Techniques for Testing the Born-von Kármán Theory of Specific Heats. W. C. Overton, Jr., and J. R. Clement, *Naval Research Laboratory.*—Two essentially independent elements enter the complete theory of the lattice heat of a crystalline solid: (1) specific heat calculations using vibration spectra based on Born-von Kármán theory, and (2) an atomic model relating the microscopic atomic force constants, α and γ, to the macroscopic elastic c_{ij}'s. Critical testing of the complete theory requires both experimental caloric and elastic data, a combination not generally available. An apparent failure of the theory would not be traceable specifically to either of the two theoretical elements by the usual testing procedures. With the appropriate theoretical calculations, one phase of our technique critically tests element (1) independently, requires only caloric data, and yields numerical values of α and γ. These calorically deduced values of α and γ may then be compared with values derived from the experimental c_{ij}'s through any atomic model,[1,2] this comparison providing an independent test of element (2). The atomic model used by Leighton[1] has been verified experimentally for copper, for which the necessary low-temperature elastic constants[3] are available.

[1] R. B. Leighton, Revs. Modern Phys. **20**, 165 (1948).
[2] J. de Launay, J. Chem. Phys. **21**, 1975 (1953).
[3] W. C. Overton, Jr. and J. Gaffney (to be published).

D6. The Thermal Conductivity of Gallium Single Crystals at Low Temperatures.* Harmon H. Plumb and Jules A. Marcus, *Northwestern University.*—The principal thermal conductivities of Gallium single crystals were measured in the liquid hydrogen and helium temperature range using helium gas thermometers. Gallium of 99.94 percent purity, obtained from the Aluminum Company of America, was grown into cylindrical single crystals (3 mm in diameter and 10 cm in length) by a method similar to that described by Powell.[1] For each specimen, the cylinder axis was parallel to one of the three principal crystallographic directions to within 5°. For one set of crystals the maxima of the thermal conductivity occurred at 6°K and yielded the ratio $c:a:b$ as 1:2:4.5 with the value 3.8 watt/cm°K for the conductivity in the c direction. Another set with maxima at 4°K yielded the ratio $c:a:b$ as 1:3.7:—with the value 10.6 watt/cm°K for the c direction. In the liquid helium range the thermal conductivity fell off rapidly with temperature extrapolating to zero at $T = 0$°K for all crystals. In the liquid hydrogen region both sets of crystals yielded a ratio of approximately 1:3:6 (as compared with 1:3.2:7 for electrical conductivities[1]) with the value 0.4 watt/cm°K for the conductivity in the c direction at 20°K.

* Supported by the National Science Foundation.
[1] R. W. Powell, Proc. Roy. Soc. (London) **A209**, 525 (1951).

D7. The Electrical and Thermal Conductivity of Magnesium and a Magnesium Alloy at Low Temperatures. D. A. Spohr* and R. T. Webber, *Naval Research Laboratory.*—The minimum of electrical resistance found at low temperatures in some of the dilute alloys of magnesium[1] is sufficiently pronounced to make possible a search for a corresponding effect in the thermal conductivity. We have measured the electrical and thermal conductivity over the temperature range 1.5 to 20°K in two polycrystalline specimens: (1) "pure" Mg, and (2) Mg$-$0.043 percent Mn. The pure specimen showed a slight minimum in electrical resistance and a thermal conductivity which followed, within experimental error, the dependence on temperature ($1/K = 1/AT + BT^2$) usually found in pure metals in this temperature range.[2,3] The dilute alloy specimen showed a much more pronounced electrical resistance minimum (ρ increased about 10 percent as the temperature was lowered from 4.2 to 1.4°K) and an exactly corresponding depression of the thermal conductivity so that the Lorenz ratio ($K\rho/T$) maintained a value of $(2.64 \pm 0.02) \times 10^{-8}$ (Volt/°K)^2 at temperatures below 4°K. These conclusions are in qualitative agreement with those reported recently by Herlin.[4]

* Now on leave at Clarendon Laboratory, Oxford.
[1] H. E. Rorschach, Jr. and M. A. Herlin, Proc. Schenectady Cryogenics Conf., p. 151 (Schenectady, New York, 1952).
[2] K. Mendelssohn and H. M. Rosenberg, Proc. Phys. Soc. (London) A65, 385 (1952).
[3] Kemp, Sreedhar, and White, Proc. Phys. Soc. (London) **A66**, 1077 (Nov. 1, 1953).
[4] Paper presented by M. A. Herlin at the Third Intern. Conf. of Low Temp. Phys. and Chem., Houston, Texas [December, 1953 (unpublished)].

D8. The Thermal Conductivity of Indium-Thallium Alloys at Liquid Helium Temperatures. Ronald J. Sladek,* *University of Chicago.*—The thermal conductivity of indium specimens containing 0, 5, 15, 20, 30, 38, and 50 atomic percent Tl have been measured as a function of temperature down to 1.3°K and as a function of applied magnetic fields below T_c. The normal state results agree at least qualitatively with the quasi-free electron theory of metals, and the superconducting state results agree with Hulm's suggestion that superconducting electrons do not scatter phonons.[1] A thermal resistivity maximum was found to accompany the isothermal destruction of superconductivity by either a longitudinal or a transverse magnetic field in specimens containing 15 percent Tl or more.[2] Scattering of phonons at boundaries between superconducting and normal regions of the specimen may be responsible for this effect.

* U. S. Atomic Energy Commission predoctoral fellow, 1951–1953. Present address: Westinghouse Research Laboratories.
[1] J. K. Hulm, Proc. Roy. Soc. (London) **A204**, 98 (1950).
[2] R. J. Sladek, Phys. Rev. **91**, 1280 (1953).

D9. The Low-Temperature Magnetization of Two Cerium Salts. Warren E. Henry, *Naval Research Laboratory.*—The $^2F_{5/2}$ ground state of Ce^{+++} with one unpaired f electron is of interest because any crystalline electric field asymmetry leaves the essential Kramers degeneracy.[1] A low-lying doublet[2] in Ce^{+++} exhibiting no hyperfine structure is convenient for low-temperature demagnetizations. Thus a sphere of small crystals of cerous nitrate hexahydrate has been magnetized to practical saturation, using a method previously described.[3] If M is plotted against H/T, superposition of magnetic isotherms is observed. A Brillouin function for $J_z = \pm\frac{1}{2}$ and $g = 2.1$ seems applicable in the range, 1.3°–4.2°K, for fields up to 60 000 gauss. Similar magnetization of $3Mg(NO_3)_2 \cdot 2Ce(NO_3)_3 \cdot 24H_2O$ was performed. Although this salt is magnetically more dilute than cerous nitrate, nonsuperposition of isotherms is observed. Since marked anisotropy[4] has already been observed for a single crystal of the double salt, a discussion will be given on the possible role of a crystalline anisotropy field in the observed nonsuperposition of isotherms.

[1] J. H. Van Vleck, *Electric and Magnetic Susceptibilities* (Oxford University Press, London, 1932), p. 296.
[2] R. J. Elliott and K. W. H. Stevens, Proc. Roy. Soc. (London) **215**, 437 (1952); W. G. Penney and R. Schlapp, Phys. Rev. **41**, 194 (1932).
[3] W. E. Henry, Phys. Rev. **87**, 229 (1952).
[4] Cooke, Duffus, and Wolf, Phil. Mag. **44**, 6 (1953); K. S. Krishman and A. Mookherji, Phil. Trans. Roy. Soc. **A237**, 135 (1938).

D10. The de Haas-van Alphen Effect in Zinc at Liquid Oxygen Temperatures. Ted G. Berlincourt and M. C. Steele, *Naval Research Laboratory.*—Recently, McClure and Marcus[1] measured the magnetic susceptibility of zinc in magnetic fields up to 9.5 kilogauss and found a field dependence in χ_{11}, the component of susceptibility parallel to the hexagonal axis, at temperatures as high as 85°K. We have extended these measurements to 25 kilogauss in the temperature range 55 to 90°K and have observed oscillations in χ_{11} equally spaced in reciprocal field as is characteristic of the de Haas-van Alphen effect. However, in the range investigated the period of oscillation β/E_0 is not temperature independent, as it is below 20°K,[2] but increases with increasing temperature. For example, β/E_0 is 6.7×10^{-5} gauss^{-1} in the region 2 to 20°K and rises to 9.8×10^{-5} gauss^{-1} at 55.4°K and 13.4×10^{-5} gauss^{-1} at 70°K. Such a temperature dependence might arise from alteration of the overlap of the pertinent Brillouin zone by the Fermi surface brought about by thermal expansion of the crystal.

[1] J. W. McClure and J. A. Marcus, Phys. Rev. **84**, 787 (1951).
[2] L. Mackinnon, Proc. Phys. Soc. (London) **B62**, 170 (1949).

D11. An Estimate of the Lifetime of Positrons in Superconductors. M. Dresden, *University of Kansas.*—It has been suggested[1] that there might be two factors which would cause the annihilation characteristics of positrons in superconductors to be different from those in normal conductors. Preliminary experiments of Talley and Stump[2] and Millett[3] appear to indicate some such effects. One of the factors involved, the change in the *ortho-para* positronium conversion rate has been investigated. It was found advantageous to use the collective description of the electron gas as given by Bohm and Pines. The estimated conversion rate depends rather sensitively on the (unknown) wave function of the system. On the basis of the qualitative nature of this wave function one may conclude that the long-lived component of the positron life time should become longer with decreasing temperature, to a limit of about 3.10^{-7} sec. The precise temperature dependence of this life time should give rather detailed information about the wave function in the superconductive state.

[1] M. Dresden, Phys. Rev. (to be published).
[2] Talley and Stump, Bull. Am. Phys. Soc. **29**, 2 Abstract G9.
[3] Millett, Bull. Am. Phys. Soc. **29**, 2 Abstract G8.

D12. (Abstract withdrawn.)

D13. Effect of Pressure on the Superconducting Transition of Tin.* M. Garber and D. E. Mapother, *University of Illinois.*—The shift in the superconducting transition curve under hydrostatic pressure has been measured for a pure single crystal ellipsoid of tin. Pressures up to 100 atmos were applied with liquid helium and the superconducting transition observed by a sensitive ballistic induction technique. Our measurements give a value of -0.0065 ± 0.0002 gauss/atmos. This value is within the range recently reported by Fiske.[1] The transition curve measured at 1 atmos is observed to be lowered by about 0.1 gauss by several applications at helium temperature of the maximum pressure. This may explain why previously reported shifts[2,3] (in which the method used prevented cycling the pressure at low temperature) are generally 15 to 20 percent greater than those of the present work.

* This work supported in part by the Office of Ordnance Research.
[1] M. D. Fiske, Houston Low Temperature Conference.
[2] Kan, Sudovstov, and Lazarew, J. Exptl. Theoret. Phys. U. S. S. R. **18**, 825 (1948).
[3] P. F. Chester and G. O. Jones, Phil. Mag. **44**, 1281 (1953).

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(continued on cover three)

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Absolute Temperature Scale between 4.2° and 5.2°K[†]

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The vapor pressure of helium has been determined between 4.25° and 5.1°K, using a constant volume gas thermometer. An equation is proposed which fits the experimental data closely, and gives temperatures which differ by a maximum of 0.02° from the currently accepted values. The reliability of the value of the boiling point of helium and the thermodynamic consistency of the properties of liquid helium near the boiling point are discussed.

INTRODUCTION

THE currently accepted temperature scale[1] between 4.2° and 5.2°K is largely based on five vapor ssure measurements by Kamerlingh-Onnes and ber,[2] all above 4.9°. The assumed shape of the vapor sure curve is not determined solely by these points, also by the fact that it must join smoothly onto more accurately known portion of the curve below 4.2°.

It has recently been suggested by Worley, Zemansky, and Boorse[3] that this accepted curve could be in error by as much as 0.06° at 4.8°. They found that an interpolation formula for the resistance of carbon resistors, which fitted vapor pressure data between 1.8° and 4.2° and at the hydrogen triple point, gave temperatures which were lower than the accepted values for helium vapor pressures above one atmosphere, and were in close agreement with values given by an extrapolation of the equation of Keesom and Lignac[4] (which fits the vapor pressure data closely between 2.2° and 4.2°).

We had need for accurate values of dP/dT in this region in order to calculate values of the vapor density from previous experiments.[5] It was noticed that values of dP/dT at 4.3° as calculated from the accurately known portion of the accepted scale and from the formula valid above 4.2° were in disagreement. This suggested that the two curves did not join sufficiently smoothly near the boiling point, where both should apply. Thus doubts were cast on the equation which had been used to fit the data of Kamerlingh-Onnes and Weber.

We have successfully used carbon resistance thermometers for thermal conductivity work between 4° and 80°K, but the discrepancies noticed by Worley *et al.* were not evident since the resistance thermometers were calibrated directly against a gas thermometer over the whole range during the course of each experiment, and an interpolation formula was not required. As our apparatus contained a vapor pressure bulb for calibrating the gas thermometer, it was possible to adapt it for an accurate determination of the helium vapor pressure between 4.2° and 5.2°K.

APPARATUS

Figure 1 is a schematic drawing of the apparatus. The copper gas thermometer (volume roughly 100 cc) is supported on the liquid helium vessel by a length of thin-walled copper-nickel tubing. The heat conduction along this tube is quite small, and the actual cooling of the gas thermometer is achieved by a method similar to that described by Swenson and Stahl.[6] The liquid helium is kept under a slight overpressure by means of

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