Finally, we should like to illustrate some of the above ideas with an example from unified field theory. It is an entirely new and a most desirable feature of the theory that the distribution of charges in an elementary particle is subject, like everything else, to a field law and is not assigned arbitrarily. If we assume that the interactions between the electromagnetic and gravitational fields are negligible, then the antisymmetric parts of our field equations,

$$R_{\underset{\vee}{\alpha B}, \gamma}+R_{\underset{\vee}{B\gamma}, \alpha}+R_{\underset{\vee}{\gamma\alpha}, B}=-p^2 I_{\alpha B\gamma},$$

reduce to

$$(\Box-\kappa^2)J_\alpha(x)=0,$$

where κ is an arbitrary constant which appears in the field equations and which under certain boundary conditions has been calculated as $\kappa^{-1}=e^2/2mc^2$; the latter is the range of the charge distribution in a charged particle. The above equation describes both signs of charge on an equal basis. For a static charge distribution we have $\rho=(e\kappa^2/4\pi)(e^{-\kappa r}/r)$, a result that may be verified experimentally by bombarding some kind of nuclear matter by high energy electrons (between 300 and 500 Mev) and studying the distribution of the emergent electrons and their cross sections. Such an experiment may also give some information about the deviation (if any) from the Coulomb interaction at distances of the order of 10^{-13} cm. Better information about charge distributions can only be obtained by solving the equations without any approximation; unfortunately this is found to be very difficult at present. The constant κ does not appear in Einstein's version of the theory. Our equations were derived by two methods, the first of which fixes the form of the Lagrangian uniquely. The existence of a constant in the field equations introduces additional terms in the Lagrangian of Einstein's theory, for which Einstein[2] remarks that (see the bottom of page 146) "All such additional terms bring a heterogeneity into the system of equations, and can be disregarded, provided that no strong physical argument is found to support them." Now, with $\kappa=0$ Einstein's charge distribution, at least to the assumed order of approximation, is given by $\Box J_\alpha(x)=0$, which implies an infinite range for the charges. Further difficulties about the theory not containing the constant κ have been discussed in detail.[1] From the results of our version of the unified field theory we infer that the nonexistence of a constant in a unified field theory implies precisely, that gravitational and electromagnetic forces are treated on the same footing and that there is nothing to differentiate between the two. It does not seem possible to derive such a constant from the field itself when there are compelling reasons for its introduction right at the beginning. The constant κ is to unified field theory what the constants c and h are to relativity and quantum theory.

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Superconductivity of Technetium

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In view of the fact that pure rhenium was recently found by Daunt and Smith[1] to become superconducting at a relatively high temperature ($T_c=2.42$°K) and in view of the chemical similarities between rhenium and technetium,[2] it was considered of interest to investigate the latter for superconductivity.

The gram-atomic paramagnetic susceptibility of technetium has been found[3] at room temperature to be approximately four times that of rhenium and hence it would follow that the electronic specific heat, $C_{el}=\gamma T$, would be considerably larger in technetium than in rhenium. The exact one to one relationship between γ and the electronic paramagnetic susceptibility per gram, valid for a free electron gas system, however, would not be expected to hold rigidly owing to the possible effects of correlation forces, as for example has been discussed for palladium and platinum by Mott and Jones.[4] On the other hand, using this information that γ for technetium is larger than for rhenium and using the empirical correlation among superconductors between γ/V and the transition temperature, T_c, put forward previously by Daunt,[5] it was concluded that if technetium were to become superconductive its transition temperature would be several times higher than that of rhenium (2.42°K).

We have investigated experimentally a powdered sample of 0.1027 g of technetium metal of purity $\geq$ 99.9 percent prepared from fission product wastes.[6] The magnetic moment was first measured as a function of the applied exterior magnetic field in the liquid helium temperature region, by using first the same apparatus as had been used previously in the measurement of the superconductivity of rhenium.[1] By calibrating the apparatus with a pure tin spherical sample of known volume, it could be determined whether the subsequently observed technetium magnetic moment was para- or dia-magnetic, and what its numerical magnitude was. These experiments showed that the technetium sample was strongly diamagnetic over the entire liquid helium temperature range from 0.9° to 4.2°K, indicating it was superconductive.

The magnetic susceptibility of the technetium sample was next investigated by a ballistic mutual inductance method in an apparatus which had been used for similar susceptibility measurements in other experiments,[7] but which was modified to allow the temperature range 4°K to 20°K to be covered. This modification consisted in placing the technetium sample inside a copper block thermally connected to its surroundings at 4.2°K only by a poorly conducting brass rod, so that the copper block could be heated electrically to any desired temperature. The temperature was measured by a carbon resistance thermometer,[8] embedded in the copper block, and calibrated in the liquid helium and liquid hydrogen temperature regions. Temperatures between 4.2°K and 14°K were computed by graphical and analytical interpolation.

Typical results showing the diamagnetic susceptibility due to the superconductivity of the technetium sample in zero external magnetic field as a function of the absolute temperature, T, using the second apparatus is given in Fig. 1. The ordinates of Fig. 1 give the deflection of the ballistic galvanometer connected to the secondary of the mutual inductance which was around the specimen, and are directly proportional to the diamagnetic susceptibility of the sample. It will be seen that, whereas the temperature, T_c, at which the last trace of superconductive diamagnetism disappears is quite sharply defined (point "A"), the transition itself is spread over a broad range of temperature. This is attrib-

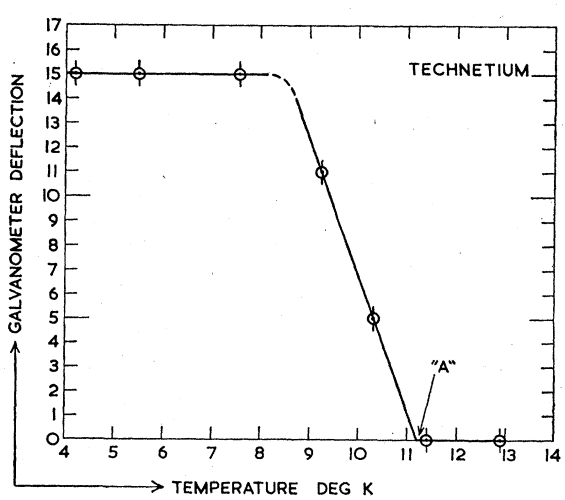

Fig. 1. Diamagnetic susceptibility (in arbitrary units) of technetium as a function of the absolute temperature.

uted largely to the geometrical form of the specimen, which having irregularly-shaped particles of different sizes, would also make the transition in a magnetic field highly irreversible.[9] A similar behavior was observed in our rhenium experiments.[1] From a number of experiments of the type illustrated in Fig. 1 the average value of the superconductive transition temperature, T_c, in zero magnetic field was found to be 11.2°K.

Similar transitions were observed in constant external magnetic fields up to 209 gauss. These transitions were found to be highly irreversible, as would be expected from the geometry of the specimen. Owing to the small quantity of technetium available for these experiments, the slope of the magnetic threshold curve could not be obtained with high accuracy, but it appeared to show $(\partial H/\partial T)_{T=T_c}$ of from 300 to 400 gauss/deg.

It is of interest to note that in Group 7 of the periodic table rhenium and technetium are superconductive whereas manganese is not,[10] and in Group 8 osmium and ruthenium are superconductive,[10] whereas iron is not.[11] It is of interest moreover that, whereas the transition temperatures of rhenium and technetium are high, that of technetium being exceptionally high, the transition temperatures of osmium and ruthenium are well below 1°K. The observed very high transition temperature of technetium is in accord with the considerations put forward earlier in this paper based on Daunt's empirical correlation among superconductors, and indeed it was expected by us some time before the experiments were undertaken. A fuller discussion of these general results in their relation to the d-band shape in the transition elements is given elsewhere by Horowitz and Daunt.[12]

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[3] Nelson, Smith, and Boyd (to be published); C. M. Nelson, Ph.D. dissertation, University of Tennessee, 1952 (unpublished), p. 64.
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[8] This was a nominal 10-ohm 1-watt radio resistor. See J. R. Clement and E. H. Quinnell, Rev. Sci. Instr. **23**, 213 (1952); Brown, Zemansky, and Boorse, Phys. Rev. **84**, 1050 (1951).
[9] See Mendelssohn, Daunt, and Pontius, Proc. Intern. Congr. Refrig., 7th Congr., The Hague, Amsterdam **1**, 445 (1936).
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Bifurcation of the *E* Region

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Effective electron measurements have been made directly in the E region by rocket-borne instruments. These data have been obtained by measuring the retardation time of a radio signal a Mc/sec or so above the critical frequency for the E region. The retardation times were found by comparing the time of arrival in the rocket of two synchronized signals sent from the ground, one of which is the probing signal and the other an uhf reference signal that suffers negligible retardation. On several occasions a profile curve relating the effective electron density *vs* altitude have been obtained for the regions between 90 and 130 kilometers.

Plots of the retardation time *vs* time of flight for the November 1946, April 1947, June and July 1953 flights from White Sands Proving Ground and Holloman Air Force Base, New Mexico are given in Fig. 1. The June and July 1953 data clearly indicate small-scale sporadic cloud effects, the study of which yields a method of "smoothing" which was applied to the November 1946 and April 1947 data with the results shown in Fig. 1. The effective electron density is found from these delay data in the following manner. Using Appleton's formula[1] with the collisional frequency, the Lorentz factor and the magnetic field set equal to zero, applying the theorem of Breit and Tuve[2] and ordinary ray-tracing techniques, one finds for the electron density, N,

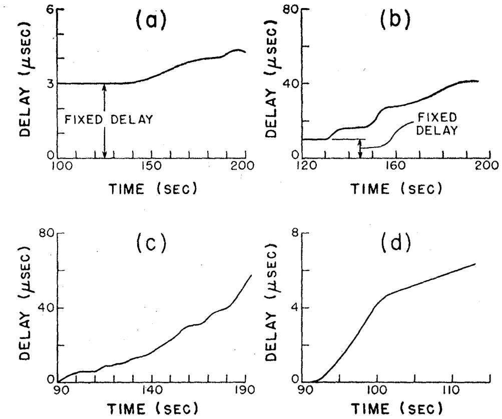

FIG. 1. Delay of probing signal *vs* time of flight of rocket. (a) 10:00 A.M., November 21, 1946; (b) 4:21 P.M., April 17, 1947; (c) 12:10 P.M., June 21, 1953; and (d) 10:52 A.M., July 1, 1953.

$$N=\left[1-K_n^2-\frac{1}{c^2(dT_n/dh_n)^2}\right]\times 1.24\times 10^4 f^2.$$

In this formula, K_n is the sine of the angle between the ray and the vertical, dT_n/dh_n is the slope of the probing signal time *versus* altitude curve, and f is the probing frequency in Mc/sec. This formula was used to reduce the delay data given in Fig. 1, yielding the plots of altitude *vs* effective electron density shown in Fig. 2.

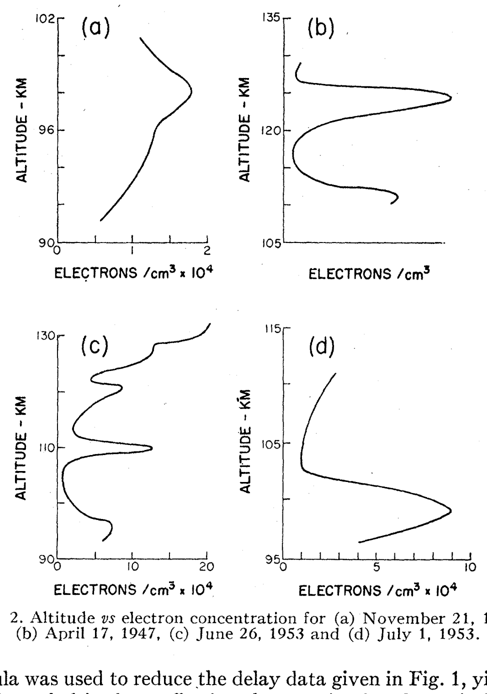

FIG. 2. Altitude *vs* electron concentration for (a) November 21, 1946, (b) April 17, 1947, (c) June 26, 1953 and (d) July 1, 1953.

Examination of these curves yield a significant result. The June 1953 and April 1947 plots show clearly a bifurcation of the E region. The maximum electron density occurs at heights of