FIG. 1. Variation of concentrations $x^{I}$ and $x^{II}$ with temperature. The experimental points were measured by Abraham, Weinstock, and Osborne.

could be generalized to the hypothesis, that $He^3$ and $He^4$ behave like a perfect mixture of $He^3$ in the normal component of $He^4$, then the free energy (2) must be replaced by

$$F=(1-x)F_4{}^0+xF_3{}^0+RT(x/x_a)\{x_a \ln x_a+(1-x_a)\ln(1-x_a)\}, \quad (4)$$

where $x_a$ is the "apparent" concentration; $N_3/(N_3+N_4{}^n)$, $y=N_4{}^n/N_4$ as before and where the connection between $x_a$, $x$ and $y$ is given by $x_a=x/(y+x(1-y))$.

The equations of equilibrium: $\mu_3{}^I=\mu_3{}^{II}$ and $\mu_4{}^I=\mu_4{}^{II}$ for the thermodynamic potentials of the components 3 and 4 in both phases I and II, derived from (4), lead to the result:

$$x_a{}^I=x_a{}^{II}, \quad (5a)$$
$$\ln(1-x_a{}^I)=-(F_4{}^{0I}-F_4{}^{0II})/RT(y^I-y^{II}). \quad (5b)$$

It is assumed that $y$ is a function of temperature *only* and independent of concentration as it should be for a perfect solution. For the high temperature phase I, $y^I=1$; whereas in the low temperature phase II, $y^{II}=N_4{}^n/N_4=(T/T_\lambda)^\nu$ with $\nu=5.6$. Equation (5a) shows that the concentrations of $He_3$ in phases I and II are no longer equal. *Therefore, the transition is no longer of the second order but becomes of the first order,* the relation between the concentrations being $x^I=x^{II}/(y^{II}+x^{II}(1-y^{II}))$. The actual calculation of the concentrations $x^I$ and $x^{II}$ as a function of the transition temperature depends on the extrapolation of the free energy curve of the high temperature phase I below $T=T_\lambda$. In Fig. 1, the results have been plotted extrapolating the entropy curve of the phase II, linearly to $\tau=0$, as has been suggested by Daunt and Mendelssohn.[6] The broken curve corresponds to a linear extrapolation of the free energy curve, as suggested in the liquid He II model of Gorter. In both cases the concentration of $He_3$ in the liquid phase at lower temperatures is extremely small, its value being approximately $x^{II}=x^I y^{II}/(1-x^I)$. The experimental points in Fig. 1 were measured by Abraham, Weinstock, and Osborne.[7]

The general formula for the vapor-liquid concentration ratio is given by

$$C^V/C^L=(1/y)(1-x_a)^{(1-y)}(P_3{}^0/P_4{}^0) \quad (6)$$

approaching to Taconis and Beenakker's formula at low concentrations.

The first-order character of the transition of phase I into phase II, which is demonstrated in Fig. 1, leads to interesting conclusions. The fact that below temperatures of about $0.5T_\lambda$ the value of $x^{II}$ is approximately zero makes it possible to speak in this temperature region of a pure phase II of $He^4$ which is in equilibrium with an ideal mixture of $He^4$ and $He^3$ in phase I. If a mixture of $He^3$ and $He^4$ of concentration $x$ is cooled down, pure liquid $He^4$ starts to be formed in a separate phase II at the transition temperature determined by $x=x^I(T)$. When the temperature is decreased still more, the amount of pure liquid $He^4$ in phase II increases, the total fraction of substance, which at a

temperature $T$ is left as a perfect mixture in phase I, being $x/x^{II}(T)$.

Of course, the present remarks must only be considered as a possibility, which is based entirely on the *hypothesis* that $He^3$ only mixes as a perfect mixture with the normal part of $He^4$ and that the interpretation in terms of the free energy expression (4) is true. A more detailed account will appear in Physica. The author is indebted to Dr. Daunt for many stimulating discussions on this subject.

[1] Fairbank, Lane, Aldrich, and Nier, Phys. Rev. 71, 911 (1947); Daunt, Probst, and Smyth, Phys. Rev. 74, 495 (1948).
[2] Sydoriak, Grilley, and Hammel, Phys. Rev. 75, 302 (1949).
[3] Taconis, Beenakker, Nier, and Aldrich, Phys. Rev. 75, 1966 (1949).
[4] Daunt, Probst, Johnson, Aldrich, and Nier, Phys. Rev. 72, 502 (1947).
[5] Daunt, Probst, and Johnston, J. Chem. Phys. 15, 759 (1947).
[6] J. G. Daunt and K. Mendelssohn, Proc. Roy. Soc. A 185, 225 (1945).
[7] Abraham, Weinstock, and Osborne, Phys. Rev. 76, 864 (1949). The author is indebted to Dr. Osborne for putting these data at his disposal before publication.

# The Beta-Spectrum of Tritium

S. C. CURRAN, J. ANGUS AND A. L. COCKROFT
*Department of Natural Philosophy, University of Glasgow,
Glasgow, Scotland*
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IN continuation of the investigation of the $\beta$-spectrum of $H^3$ reported elsewhere,[1] a more detailed study has been made of the shape of the spectrum near the end point. The proportional counter technique previously described[2] has again been used with a photographic method of recording and analyzing the output pulses.

This study was designed to increase the accuracy of the determination of the shape of the spectrum close to the end-point energy $E_0$, and also to obtain a more accurate estimate of the correction which must be made to the spectrum in view of the experimental limitations resulting from the finite resolution of the instrument.

Energy calibration was provided by a beam of $K_\alpha$ x-rays of molybdenum (17.4 kev). The half-width for half-intensity for this line was 900 ev ($\sim$5 percent), and the parts of the theoretical Fermi curves shown in Fig. 1 have been modified to allow for the spread arising from a resolution corresponding to this line width. The curves have been calculated for true upper energy limits ($E_0$) of 18.0 and 18.6 kev with a neutrino mass $\mu=0$ kev, and for $E_0=18.0$ kev and $\mu=1$ kev. They may therefore be compared directly with the observed experimental points. For $\mu=0$ the points lie between the two curves for $E_0=18.0$ and $E_0=18.6$ kev, which brings our results into rather close agreement with those of Hanna and Pontecorvo;[3] the higher energy value would also give slightly better agreement with the theoretical Fermi curve over the whole energy range previously investigated.[1] Alternatively, for $E_0=18.0$ kev, it may be assumed that $\mu$ lies between 0 and 1
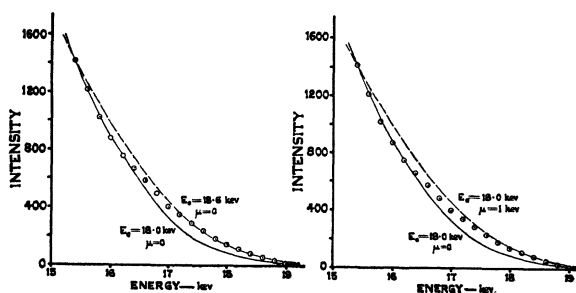


FIG. 1. Comparison of experimental and theoretical Fermi curves for tritium near the end point.

kev, in agreement with our earlier interpretation. It appears, however, that the line width is too large to allow a significant differentiation between these two cases; it has been pointed out already[2,4] that this line width arises principally from variations about the average number of ion pairs produced by the $\beta$-rays in the initial ionization process, and it is unlikely that the uncertainty will be resolved by relatively slight increases in the accuracy of measurement.

We should like to take this opportunity of thanking Professor P. I. Dee for his advice throughout the work and we are indebted to Dr. W. B. Lewis for a number of helpful comments and suggestions.

[1] Curran, Angus, and Cockroft, Nature 162, 302 (1948); Phil. Mag. 40, 53 (1949).
[2] Curran, Angus, and Cockroft, Phil. Mag. 40, 36 (1949).
[3] G. C. Hanna and B. Pontecorvo, Phys. Rev. 75, 983 (1949).
[4] Hanna, Kirkwood, and Pontecorvo, Phys. Rev. 75, 985 (1949).

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## On Positive Excess of Meson Component near Sea Level

P. Bassi, E. Clementel, I. Filosofo, and G. Puppi
*Centro per lo Studio degli Ioni veloci del CNR, Istituto Fisico dell'Università di Padova, Italy*
August 3, 1949

THE scarcity of experimental data concerning the distribution of positive excess in the meson spectrum and the common opinion that the positive excess is closely related to the meson production by the $N$ component, lead us to perform an experiment at sea level, in which positive and negative mesons are separated by means of a magnetic field of 14,000 gauss in air. The experimental apparatus is shown in Fig. 1.

The upper telescope consists of five channels of double coincidences $1-1$, $2-2\cdots5-5$, which limits a not strictly convergent beam of cosmic rays traversing the central region of magnetic field. The field focuses particles of $pc = 2\,2\cdot10^8$ ev which are revealed by counters $CDE$; $C'D'E'$.

Putting in $S$ 4.7 cm of lead, fivefold coincidences register only mesons, the fourfold, besides mesons, protons and electrons. The absorber $T$ has the object of degradating the energies of incident
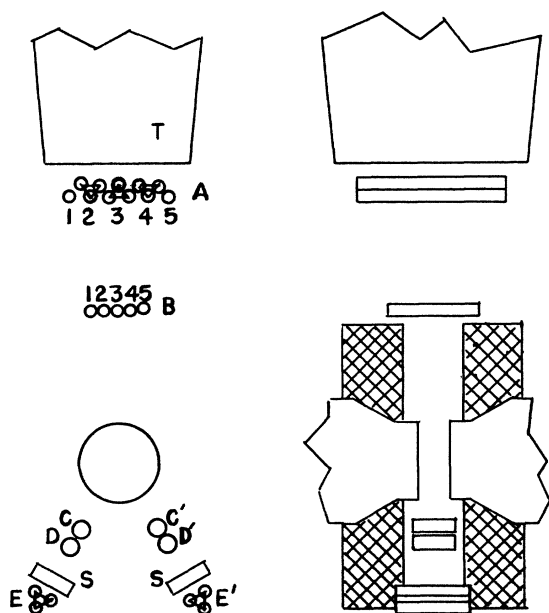


Fig. 1. Counter arrangement.

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TABLE I. Experimental results for coincidence rates.

| Absorber thickness (g/cm² Pb) | Counts per hour | $\delta$ | [IV-V]⁻ | [IV-V]⁺ |
|---|---|---|---|---|
| 290 g/cm² | 1.18 ±0.06 | 0.16 ±0.10 | 0.13 ±0.03 | 0.04 ±0.02 |
| 540 g/cm² | 1.36 ±0.06 | 0.22 ±0.12 | 0.10 ±0.06 | 0.02 ±0.04 |
| 1150 g/cm² | 1.14 ±0.05 | 0.25 ±0.07 | 0.20 ±0.04 | 0.04 ±0.05 |

particles. Experimental results and their probable errors are reported in Table I.

In the second column counts per hour are shown, they agree with the Wilson spectrum. In the third column, the excess as commonly defined by

$$\delta = 2\frac{N_+ - N_-}{N_+ + N_-}$$

is indicated.

The first two plots are in a good agreement with the previous data by Nereson[1] and Conversi, Pancini, and Piccioni;[2] the value of the excess in the third plot, on the contrary, is remarkably high, and indicates that, at least for energies up to 2 Bev, the excess does not decrease. This is in agreement with a recent isolated result by Brode[3] who finds an excess about 0.3 for energies from 1.4 to 2 Bev. The fourth column indicates the number of negative particles per meson whose energies are about $2.2\times10^8$ ev and which do not penetrate 4.7 cm of lead. They should in the first line be interpreted as knock-on electrons. The fifth column is concerned with positive particles that we may explain as protons, but the last data are less significant because of large errors.

The present results may be explained in terms of multiple meson production with the existence of two sources distributed in the atmosphere, of which the first formed by mesons created in the first collision by primary protons is substantially responsible for the excess A detailed paper will be submitted for publication in *Nuovo Cimento*.

[1] N. Nereson, Phys. Rev. 73, 565 (1948).
[2] Conversi, Pancini, and Piccioni, Phys. Rev. 71, 209 (1947).
[3] R. B. Brode, Phys. Rev. 76, 468 (1949).

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## Heat Flow in Metals below 1°K and a New Method for Magnetic Cooling

C. V. Heer and J. G. Daunt
*Mendenhall Laboratory, Ohio State University, Columbus, Ohio*
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MEASUREMENTS have been made of the thermal conductivities of tin and tantalum both in the superconducting and normal states in the temperature range 0.2° to 1°K and experiments have been carried out on the question of thermal contact by heat flow through superconductors in this temperature range. The preliminary results of these experiments may be of interest in connection with two stage magnetic cooling methods, such as have been proposed for the study of nuclear paramagnetism[1] and consequently are reported herewith. In addition the experiments have led to a convenient method for adiabatic magnetic cooling.

The general experimental arrangements consisted of two chromium potassium alum ellipsoids (one approximately five times the volume of the other) separated from one another by a distance of about 10 cm and connected thermally by the superconducting metal specimen under investigation. The salt-metal connection was made by high pressure molding of the salt powder. The salt ellipsoids were differentially cooled to low temperatures by the magnetic method,[2] and the thermal conductivity of the metal link between them calculated from observations of the rate