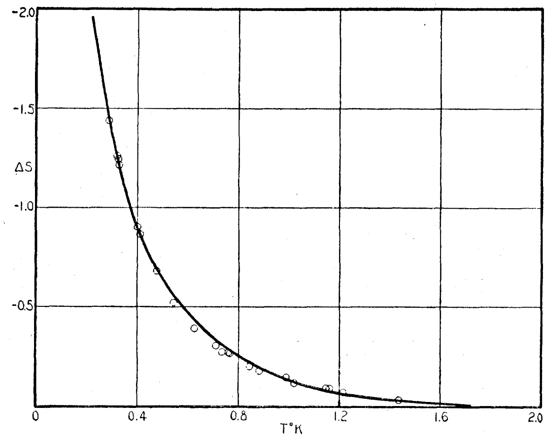


FIG. 1. Decrease in entropy below 1.7°K for $\frac{1}{2}$ mole of $Gd_2(SO_4)_3 \cdot 8H_2O$. The curve is calculated.

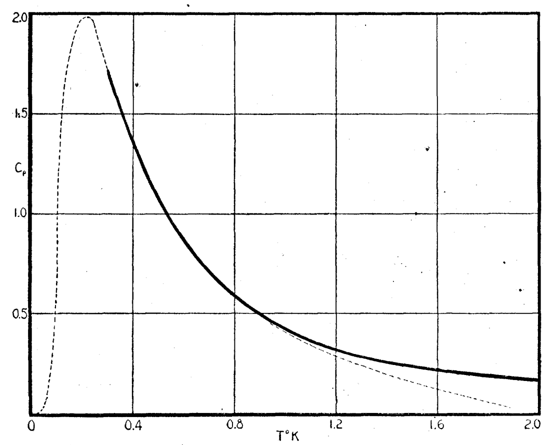


FIG. 2. Heat capacity in calories per degree for $\frac{1}{2}$ mole of $Gd_2(SO_4)_3 \cdot 8H_2O$.

was the distance between the coupled pair of gadolinium atoms. From the experimental data this was evaluated to be $3.5 \times 10^{-8}$ cm. This is a reasonable order of magnitude since the distance would be $5.9 \times 10^{-8}$ cm if uniform distribution of gadolinium atoms in $Gd_2(SO_4)_3 \cdot 8H_2O$ were assumed. The agreement shown by Fig. 1 is quite good but this should certainly not be taken as indicating that our geometrical assumptions are even approximately correct.

It is our purpose merely to show that any reasonable interaction theory will give an equation approximating the form indicated by our data. With the above assumption 64 states result from the possible couplings of the eight states known to exist in the case of a free gadolinium ion.

The data are also in quite good agreement with an equation proposed by Kürti.[3] Kürti assumed eight equally spaced levels with each atom acting independently. How ever, we believe that the extensive investigations of Kamerlingh Onnes and his associates on the effect of magnetic dilution on susceptibility measurements, demonstrate that the interaction mechanism is responsible for the observed heat capacity.

Heat capacities obtained from the data by means of the relation $dS/dT = C_p/T$ are in reasonably close agreement with those given by the theoretical equation. This is evident from Fig. 1. We have therefore shown that theoretical heat capacity curve in Fig. 2. The dotted portion below 0.28°K represents extrapolation. Above 1°K the dotted theoretical curve gives results that are too low. The upper solid curve above 1°K represents a junction of our experimental curve with that of Kürti, who has made calorimetric heat capacity measurements down to a temperature of 1.6°K. Our results near 1.6°K are lower than those of Kürti near this temperature, which probably marks the region of lowest accuracy in both investigations.

In connection with the theoretical equation it should be pointed out that an *a priori* weight of two is given to the lowest energy level by the assumption of isolated pairs of atoms. This leads to a zero point entropy of $\frac{1}{2}R\ln 2$ per gram atom of gadolinium. The consideration of more extensive atomic coupling would reduce this, until as a limit the zero point entropy would disappear from the expression. This would cause the heat capacity curve to drop off less rapidly on the low temperature side of the maximum.

It may be of interest to mention that the lower temperatures were measured with a precision of about three ten-thousandths of a degree. The principal uncertainty in the results was caused by fluctuations in the current available for the magnet.

The above results are preliminary and the work will be repeated and extended under more favorable experimental conditions. The temperatures which have been obtained from an extrapolation of magnetic data will be placed on the thermodynamic scale.

A rough estimate shows that with a field of 8000 gauss and a starting temperature of 1°K, $Gd_2(SO_4)_3 \cdot 8H_2O$ should produce a temperature slightly below 0.2°K. With a field of 20,000 gauss at 1°K, the final temperature should be about 0.1°K. With increasing magnetic dilution, it should be possible to extend these estimates to still lower temperatures.

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[3] Kürti, Zeits. f. physik. Chemie **20**, 305 (1933).

## Disintegrations of Neon Nuclei by Fast Neutrons

Thirteen disintegrations of neon nuclei have been obtained in 3200 pairs of photographs of a Wilson cloud chamber through which neutrons were passing. In at least four of these the neutron seems to have been captured. The energy relations of these events were calculated on the basis of the assumption that the reaction which occurs is:

$$\begin{array}{ccccccc} Ne^{20} & + & n^1 & \rightarrow & O^{17} & + & He^4 \\ (19.9967\pm0.0009) & + & (1.0067-E) & \rightarrow & (17.0032-E'\pm0.003) & + & (4.00216\pm0.0004). \end{array}$$

Here $E$ represents the energy converted into a $\gamma$-ray in the formation of a neutron from boron and $E'$, the similar value for the formation of $O^{17}$ from $N^{14}$ by the capture of an alpha-particle by the latter. If $E$ and $E'$ are both zero, then 0.002 unit of mass or $1.9\times10^6$ electron-volts must be supplied. Since $E$ is probably larger than $E'$, the amount of energy which must be supplied is probably greater than $2\times10^6$ electron-volts.

The velocity $v_n$ of the neutron, its kinetic energy $KE_n$, the kinetic energy $-\Delta KE$ which disappears in the reaction, and the energy which presumably escapes in the form of a $\gamma$-ray are given in Table I.

TABLE I.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $v_n\times10^{-9}$ cm/sec. | 3.9 | 4.5 | 5.3 | 5.1 |
| $KE_n\times10^{-6}$ e.v. | 7.8 | 10.6 | 14.5 | 13.4 |
| $-\Delta KE\times10^{-6}$ e.v. | 5.0 | 5.9 | 10.6 | 6.9 |
| Energy of $\gamma$-ray$\times10^{-6}$ e.v. | 3.1 | 4.0 | 8.7 | 5.0 |

The average energies in millions of electron-volts of the neutrons which have been found to disintegrate light nuclei are 5.8 for nitrogen, 7.0 for oxygen, and 11.6 for neon. The value for oxygen is taken from the work of Feather. The number of disintegrations from which the averages were taken is 19 for nitrogen but only 4 each for oxygen and neon. While the number is too small to show definitely what the relations are, it seems probable that the energy necessary for disintegration increases rapidly in the order $N^{14}$, $O^{16}$, $Ne^{20}$. The mass values indicate that the energy needed to supply mass in each of the reactions increases in this order. The actual values are uncertain but those now accepted indicate that the change of mass is equivalent to a decrease of $1.4\times10^6$ e.v. for nitrogen, a conservation of mass for oxygen, and an increase of $1.9\times10^{+6}$ e.v. for neon.

The kinetic energy which disappears in the disintegration of neon varies from 5.0 to $10.6\times10^6$ e.v. Of this, from 3.1 to $8.7\times10^6$ e.v. is presumably converted into a $\gamma$-ray. It is of interest that neon seems to follow the rule found for nitrogen and oxygen, which is that in every disintegration by capture kinetic energy is found to disappear, except that with nitrogen it may occasionally be conserved. In no case is there an increase of kinetic energy.

The range-energy relations for $O^{17}$ in neon are somewhat uncertain, and so the values given above should in this respect be considered as preliminary.

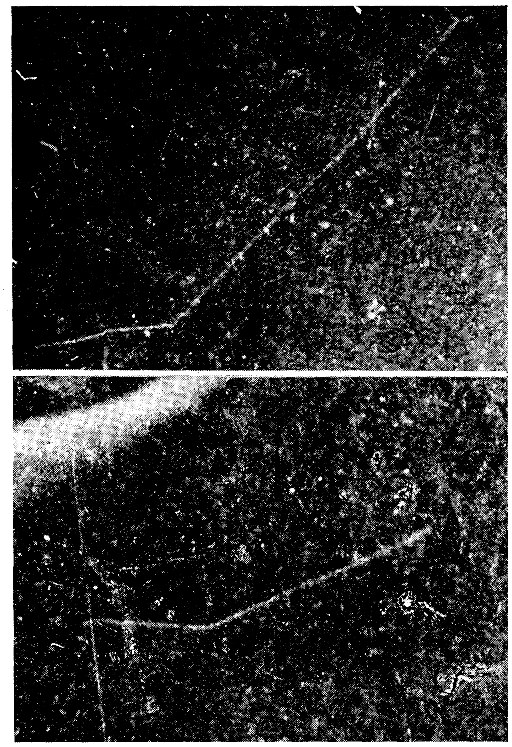

FIG. 1. Stereoscopic views of the disintegration of a neon nucleus by capture of a neutron.

The figure is a reproduction of a photograph of the disintegration of a neon nucleus by a neutron.

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## On The Production of Positive Electrons by Electrons

The experimental discovery of the positive electron makes possible, as has recently been observed by Oppenheimer and Plesset,[1] a consistent development of Dirac's theory of the electron, in which the appearance of pairs (electron and anti-electron) plays an important part. It appears that, in the experimental production of the pairs, the Coulomb fields, especially those of nuclei, are most important. In this case the theory shows that radiation of energy greater than $2mc^2$ is required for their production. Oppenheimer and Plesset have made a preliminary study of the production of pairs by $\gamma$-rays; we have carried through the analogous work for their production by high energy electrons (and positives). For $\gamma$-rays it appears, both from OP and from the experiments of Anderson, that the production of pairs becomes increasingly important as the energy of the $\gamma$-rays is increased; we have wanted to see whether this

[1] J. R. Oppenheimer and M. S. Plesset, Phys. Rev. **44**, 53 (1933) (hereafter referred to as OP).

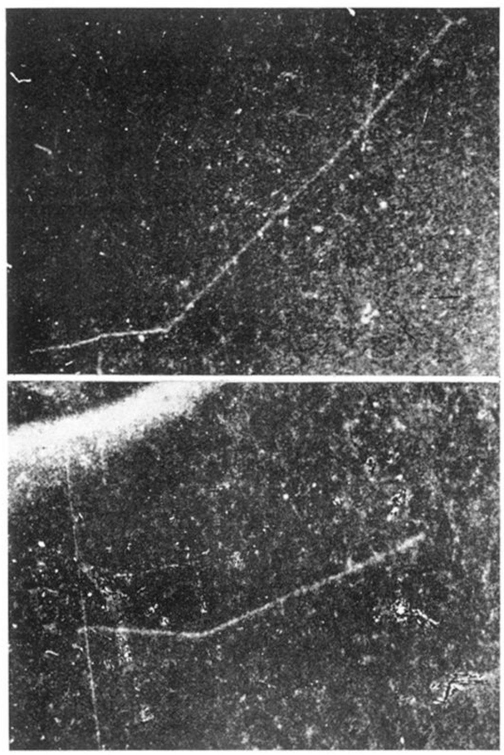

FIG. 1. Stereoscopic views of the disintegration of a neon nucleus by capture of a neutron.