Some Generalizations of the β Transformation Theory

According to a hypothesis of Pauli, worked out in detail by Fermi and others,[1] the emission of an electron in the process of β transformation must be accompanied by simultaneous emission of a neutrino in order to satisfy the conservation of spin and energy ($n\rightarrow p+e^{+}+\nu$ or $p\rightarrow n+e^{-}+\nu$). We should like to discuss here the possibility of two other similar processes: *The emission of a pair of electrons* ($n\rightarrow n+e^{+}+e^{-}$ or $p\rightarrow p+e^{+}+e^{-}$) and *the emission of a pair of neutrinos* ($n\rightarrow n+\nu+\nu$ or $p\rightarrow p+\nu+\nu$). Such processes evidently do not correspond to nuclear transformations though they could occur together with γ-radiation if the nucleus is excited.

These processes may be of importance for the explanation of forces between heavy particles and also their magnetic moments. In principle, such an explanation was given[2] on the basis of (e, ν) pair emission (ordinary β transformation); however, for both effects the calculated results (accepting U–K interaction) were too small by a factor of about 10^{12}. Considering the interaction forces and magnetic moments as due to (e^{+}, e^{-}) or (ν, ν) pair emission, however, we can obtain the correct values, since we have considerable freedom in choosing the probabilities for these new processes. We shall ascribe the above two effects to (e^{+}, e^{-}) emission because, in order to give a reasonable explanation of magnetic moments of heavy particles, the momentary emission of pairs possessing sufficiently large magnetic momenta is needed.

In the case of (e^{+}, e^{-}) emission (and also (ν, ν) emission) the charge of the heavy particle remains unchanged, although the spin may change. This seems to correspond to the fact that *forces between heavy particles depend on their spins but not on their charges*. Indeed, experimental evidence shows that the (n, p) and (p, p) forces are equal if the spins of two particles are antiparallel.[3] The (n, p) force for parallel spins is an attraction and we conclude that the same is true for the (p, p) force. Thus, apart from Coulomb forces, *attraction between any pair of heavy particles* results. If we furthermore assume that the total potential energy of a nucleus is a sum of interaction energies of separate pairs, then, owing to *the absence of valency saturation* for our type of exchange-phenomena, heavy nuclei would collapse to a radius comparable with the range of forces between constitutional particles.[4] Therefore, we must assume that the *interaction between two particles must be affected (reduced) by the presence of other particles*. If *several pairs may be exchanged simultaneously between two or several heavy particles*,[5] such an effect can be easily understood. It has been shown by perturbation calculations that a perturbing potential which leads to a correct magnitude of interaction gives rise to high order perturbations which converge rather slowly;[6] from this it follows that the abovementioned simultaneous exchange of several pairs may possess a considerable probability. Assuming that the probability of (e^{-}, e^{+}) transformation is 10^{12} times larger than the probability of the ordinary (e, ν) transformation, *attractive forces and magnetic moments can be described quantitatively*. This assumption would also lead to (e^{-}, e^{+}) *pair emission from excited nuclei*, which process would compete with the γ-ray emission whenever the excitation energy exceeds 2 mc^{2}. If the (e^{-}, e^{+}) pair is emitted with one mv total kinetic energy, the probability would be 10^{9} sec.$^{-1}$ ($10^{12}\times\beta$ decay constant for this energy) which, for heavy nuclei, is comparable with the probability of the Dirac pair formation by γ-rays in the vicinity of the emitting nucleus.[7]

It seems reasonable to expect that the ratio of the probabilities of (ν, ν) and (ν, e) emissions is of the same order of magnitude as for (ν, e) and (e^{+}, e^{-}) emission. This would lead to comparable probabilities for (ν, ν) pair emission and for the emission of quanta of gravitational radiation.[8]

G. Gamow
E. Teller

George Washington University (GG and ET),
Carnegie Institution of Washington (GG),
Washington, D. C.,
January 19, 1937.

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[1] E. Fermi, Zeits. f. Physik **88**, 161 (1934); G. Uhlenbeck and K. Konopinski, Phys. Rev. **48**, 7 (1935).

[2] D. Iwanenko and I. Tamm, Nature **133**, 981 (1934); C. Wick, Rend. R. Nat. Acad. **21**, 170 (1935); C. Weiszäcker, Zeits. f. Physik **102**, 572 (1936).

[3] M. A. Tuve, L. R. Hafstad, and N. P. Heydenburg, Phys. Rev. **50**, 806 (1936); G. Breit, E. Condon, and R. Present, Phys. Rev. **50**, 825 (1936).

[4] W. Heisenberg, Rapports de Congres Solvay, 1933.

[5] D. Iwanenko and A. Sokolow, Nature **138**, 684 (1936); L. and G. Nordheim, Phys. Rev. (in press).

[6] H. Bethe and R. Bacher, Rev. Mod. Phys. **8**, 82 (1936).

[7] R. Oppenheimer and M. Plessett, Phys. Rev. **44**, 53 (1933).

[8] A. Einstein, Berlin, Sitzber. Akad. Wiss. 688 (1918).

Isotopic Constitution of Neodymium

In a previous paper an example of a mass spectrum obtained from a mixture of rare earth elements was given.[1] This included masses at 148 and 150 which could not be identified with any known isotopes. Dr. Aston has suggested[2] that they are new isotopes of neodymium. I have recently analyzed the ions from a spark between fairly pure neodymium electrodes, and find that the masses at 148 and 150 belong to this element (Fig. 1). The faint mass at 141 is probably due to a trace of praseodymium. No other impurities were found.

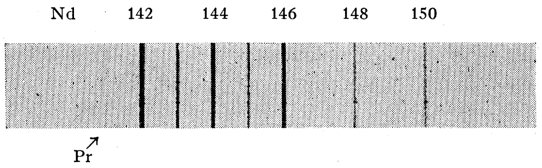

FIG. 1. Mass spectrum of neodymium.

Samarium ions were obtained from sparks to an electrode made by filling a nickel tube with a mixture of samarium oxide and aluminum. The isotopic constitution was found to be the same as that observed by Dr. Aston with the abnormal intensity relationships among the isotopes reported by him.

A. J. Dempster

Ryerson Physical Laboratory,
University of Chicago,
Chicago, Illinois,
February 1, 1937.

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[1] Proc. Am. Phil. Soc. **75**, 735 (1935).

[2] F. W. Aston, Nature **137**, 613 (1936).