Evidence for a New Type of Nuclear Reaction

A 33-minute period was observed when sulphur was bombarded with 0.1μa of 22-Mev He^{++} ions accelerated by the Harvard cyclotron. This was identified as a chlorine activity by dissolving the irradiated sulphur in CS_2, adding dilute HNO_3 and a drop of HCl, and precipitating the chlorine as AgCl by the addition of $AgNO_3$. By bending the electrons in a magnetic field their sign was found to be positive. This test excludes all chlorine isotopes that might be formed by an (α, p) reaction with the exception of Cl^{36}. However, the latter is known to have a period greater than 1 year.[1]

Radioactive Cl^{34} is a positron emitter of 33-min. half-life.[1] It can be formed from phosphorus by the reaction P^{31} $(\alpha, p)Cl^{34}$ and from sulphur by S^{33} $(d, n)Cl^{34}$. Phosphorus was bombarded with α-particles and an absorption curve was obtained for the 33-min. activity. Similar data were taken for the 33-min. activity induced in sulphur by α-particles. A comparison of the two absorption curves showed that the two were identical within the limits of experimental error.

A series of tests were then made to show that the observed activity in sulphur was not due to phosphorus contamination. Chemical analysis of the sulphur indicated that there was less than 0.001 percent of phosphorus. By comparing the relative strengths of the 33-min. period in sulphur and in phosphorus, it was concluded that at least 1.5 percent contamination in the sulphur would be required to yield the observed activity. To eliminate the possibility of deuteron contamination in the He^{++} ion beam, sulphur was bombarded with 11-Mev deuterons. The resulting 33-min. activity when compared with the α-particle induced activity indicated that 50 to 100 percent of the He^{++} ion beam must have been D^{+} ions if the latter were responsible for the observed activity. However, visual observations of the He^{++} ion beam and tests with carbon as a monitor showed that there was less than 1 percent of deuteron contamination. Furthermore, the $S+He^{++}$ and $S+D^{+}$ total decay curves are quite distinct.

These tests indicate that the 33-min. period is to be identified as Cl^{34}. Since the lightest stable sulphur isotope is 32, the most reasonable assumption seems to be that Cl^{34} is formed from S^{32} by the reaction S^{32} $(\alpha, d)Cl^{34}$ or S^{32} $(\alpha, pn)Cl^{34}$.

Reactions of the (α, d) or (α, pn) type are highly endoergic with thresholds in the neighborhood of 10 Mev. It should be possible to decide between the two types by threshold measurements, since the latter requires 2.2 Mev more energy than the former (corresponding to the binding energy of the deuteron).

No evidence has been found for a 1.1-hour period reported by King, Henderson, and Risser.[2] Two very weak activities of 3.3 hours and >8 days were observed but have not been identified.

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The Production and Half-Life of Chlorine 33

The series of radioactive elements characterized by the formula $Z-N=1$ is of importance to the theory of nuclear structure since, as Wigner[1] has shown, it is possible to calculate on simple assumptions, the energy release in the positron decay, and further by the use of the Sargent relationship, the half-life may be predicted. The properties of the members of the series have been studied[2] (with a few exceptions) up to $Z=14$. We have recently measured the half-life of a short-lived radioactive element which is almost certainly $_{17}Cl^{33}$, a high member of the series. The measured half-life of 2.8 seconds[3] is too short to allow a chemical verification of the assignment to be made, so one must rely on physical evidence, which is presented below.

Sulphur of high purity was bombarded with 8-Mev deuterons in an atmosphere of helium (to eliminate recoil products from the disintegration of air atoms). A swinging arm carried the target from the bombarding chamber to an ionization chamber and Dershem electrometer located behind the yoke of the 37″ cyclotron in less than one second after the end of the activation. Readings were permanently recorded on a kymograph.

The record showed a decay curve which could be analyzed into two components of 2.5 min. and 2.8 sec. The former is P^{30} formed in the known reaction of $S^{32}+d \rightarrow P^{30}+\alpha$. The short period gives an exponential decay over a factor of 100 in intensity. The saturation activities of the two periods are almost the same, which would rule out the possibility that the short one was due to a contamination or to any of the rare sulphur isotopes. The only other common type of reaction to be expected is $S^{32}+d \rightarrow Cl^{33}+n$. A $(d, 2n)$ reaction giving rise to Cl^{32} can almost be ruled out on energetic grounds. We therefore conclude that the 2.8-sec. period is due to the decay of Cl^{33} in the reaction $Cl^{33} \rightarrow S^{33}+e^{+}$.

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[2] M. G. White, L. A. Delsasso, J. G. Fox and E. C. Creutz, Phys. Rev. **56**, 512 (1939).
[3] A more exact value, together with the details of the experiment will be published later.