added to a nucleus without the ejection of some other particle to carry away the excess energy is extremely small. So far no example of it has been established.

The second type of reaction seems more attractive, since any excess energy could easily be carried away by the neutron. If we take the masses of the proton, neutron and positron as 1.0072, 1.0067 and 0.0005, respectively, then the only kinetic energy available for the neutron and the positron is the kinetic energy contributed by the incident proton (in this case 0.9×10^6 e.v.). Nevertheless, we may not be justified in expecting to find the energies of the positrons limited to 0.9×10^6 e.v., since the known phenomena of the continuous β-ray spectrum[9] have already indicated that the strict law of the conservation of energy may not hold in the case of electron emission. It might be reasonable to expect, however, that the energies of the positrons plus those of the neutrons would satisfy the conservation of energy statistically, and therefore have 0.9×10^6 e.v. as a mean energy.

In a preliminary set of cloud-chamber photographs taken by Dr. Carl D. Anderson and Mr. Seth H. Neddermeyer of carbon after proton bombardment, tracks appear having energies distributed up to above 10^6 e.v. It is interesting to note that the positron energy spectrum is continuous, as in the case of the β-rays, and that some of the positrons come off with energy in excess of the 0.9×10^6 e.v. which would be available on the above assumptions as to reaction and mass. More detailed data regarding the energy spectrum will be published by Anderson and Neddermeyer. A more precise knowledge of the mass of the neutron will be necessary for the further study of the energy relations—both elementary and statistical—in these processes.

Radioactive gases from C and B_2O_3

In observing the activity of a B_2O_3 target in a cloud chamber after deuton bombardment, it was noticed after a short time that a large number of tracks appeared which originated in the gas. Although it has been assumed that the radioactive substance in this case is C^{11}, the above observation would indicate that the active material is a gas which rapidly diffuses out of the B_2O_3. As further evidence, we found that warming the active B_2O_3 to about 200°C in air completely drove off the radioactive constituent. It therefore seemed desirable to collect, and if possible, determine the nature of the active gas. To do this we warmed a small amount of the activated B_2O_3 in a flask containing air, and transferred the air into an ionization chamber, through a liquid air trap. As long as the chamber was protected by the liquid air, no activity was recorded. However, upon removing the liquid air and allowing the trap to rise to a temperature considerably above that of liquid air, a large amount of the active material then made its appearance in the chamber. The B_2O_3 which was left in the flask was afterwards tested and found to have no activity. From this we conclude that after the B_2O_3 is bombarded, nearly all the C^{11} exists in the target as CO or CO_2, and very little, if any, as carbon. It should be noted that in measuring the period of decay of this substance, any method in which the gas is not prevented from escaping will lead to an apparent period which is considerably shorter than the real period. In order to make certain that the effect observed from B_2O_3 was due to the boron, and not to the oxygen, a target of SiO_2 was bombarded with deutons and tested for activity. No measurable effect was found, so it can be assumed that the oxygen contributes little, if any, of the effect.

A graphite target after bombardment with deutons, which supposedly contained N^{13}, was also heated in an effort to drive off the active constituent, but after heating to a red heat, about half the activity remained in the target. This result does not necessarily cast doubt upon the belief that the active substance is N^{13}, because we know that nitrogen, as well as other gases, is very strongly adsorbed on carbon.

We wish to acknowledge our gratitude to the Seeley W. Mudd Fund for the support of this work.

H. R. CRANE
C. C. LAURITSEN

Kellogg Radiation Laboratory,
California Institute of Technology,
March 14, 1934.

Energy Spectra of Positrons Ejected by Artificially Stimulated Radioactive Substances

Curie and Joliot[1] have reported that under the bombardment by α-particles from Po, several of the light elements, *viz.*, B, Mg, Al undergo transmutations which result in the production of radioactive isotopes which have half-lives of the order of several minutes and disintegrate by the ejection of positrons. Lauritsen, Crane and Harper[2] have produced such radioactive substances artificially by the bombardment of various light elements with deutons and protons accelerated to 900,000 e-volts energy. They have very kindly supplied us with several samples of C, B, Be and Al freshly subjected to proton or deuton bombardment. By inserting these samples in a cloud chamber operating in a magnetic field of 800 gauss it was shown that in all cases so far tested the disintegration results in the ejection of positrons of varying energies up to about 1.5 million e-volts. No α-particles or protons are observed and no tracks which can with certainty be ascribed to disintegration negatrons. For convenience we refer in the following to the element bombarded rather than to the supposed radioactive product. A discussion of the various nuclear reactions is being given by Dr. C. C. Lauritsen and H. R. Crane.

The samples so far tested are given in Table I.

When the activated B_2O_3 target was inserted in the chamber a large number of tracks were observed which did not originate in the target itself. Stereoscopic photographs taken with the magnetic field adjusted to the high value of

[1] Curie and Joliot, Comptes Rendus **198**, 254 (1934).
[2] Lauritsen, Crane and Harper, Science **79**, 234 (1934).

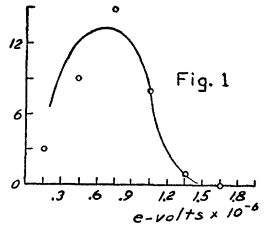
TABLE I.

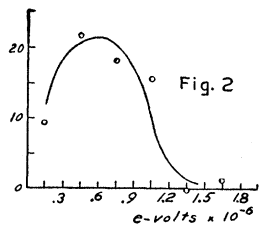
Target	Projectile	Type of disintegration	Energy distribution
Be	Deutons	Positron	See Fig. 1
B_2O_3	"	"	" " 2
C	"	"	" " 3
Al	"	"	" " 4
C	Protons	"	" " 5

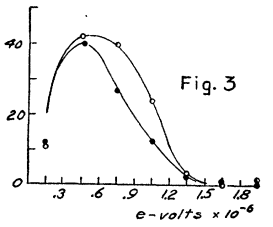
19,000 gauss showed that a large percentage of the tracks originated in the gas in all parts of the chamber. After the removal of the source the gas remained active and several tracks per expansion were obtained. This showed that the active element was present as a gas and diffused from the target throughout the chamber. Lauritsen and Crane have subsequently found evidence that the gas in this case is CO or CO_2, in which the carbon is the radioactive C^{11}.

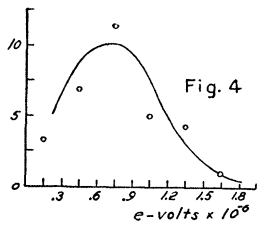
Though these targets, because of the short range of the impinging deutons or protons compared with those of the ejected positrons should be in all cases essentially thin targets, the diffusion of the active material deeper into the target may in some instances introduce an absorbing layer for the positrons to penetrate before they emerge into the chamber for energy measurement. The energy distributions obtained by using a thick carbon target and those obtained using a very thin layer of paraffin as target are very much the same and show that in no case can the energy distribution be markedly affected by energy loss of the positrons before observation. See Fig. 3.

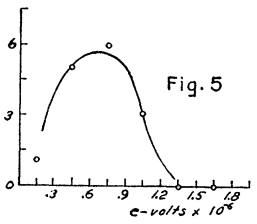
From all targets the positrons emerged with a wide distribution in energy similar to the β-particles from natural radioactive substances. It is, however, not possible on the basis of our present data to make an accurate comparison between energy distributions for the two types of disintegrations. As in ordinary β-disintegration there is here no indication that the disintegration probability is different in different parts of the energy spectrum. All the distribution curves show a striking similarity with one another with the possible exception of Al. The Al data suggest a higher energy limit and Al has a shorter half life than the lighter elements, B and C. To find whether a relation exists between the maximum energy of the bombarding projectiles and the maximum disintegration energy the writers plan to study targets activated by higher or lower energy protons or deutons. This together with an investigation of the neutrons emitted during bombardment may throw light on such questions as the difficulties of energy conservation in β-disintegration, and the mass of the neutron.











Numbers of positrons in 300,000 volt intervals plotted as a function of energy. The general shape of the smooth curves was obtained by plotting the track counts in overlapping energy intervals but only one set of points is shown.

FIG. 1. Be target bombarded with deutons.
FIG. 2. B target with deutons.
FIG. 3. ●, Very thin paraffin target with deutons; o, C target with deutons.
FIG. 4. Al target with deutons.
Fig. 5. C target with protons.

In the case of Be it is possible that the activity was due to carbon contamination, but this is not likely because of the large activity shown by the Be target.

SETH H. NEDDERMEYER
CARL D. ANDERSON
Norman Bridge Laboratory of Physics,
Pasadena, California,
March 15, 1934.

The Spectrum of Singly Ionized Europium

The main energy levels of Eu II are found to result from the addition of an electron to the common parent term, $4f^7(^8S°)$, of Eu III. The basic levels are $6s\ ^9S_4°$ and $6s\ ^7S_3°$, which result from adding a $6s$ electron to the parent term. The frequency difference of 1669.27 cm^{-1}, which is now shown to be the separation between $^9S_4°$ and $^7S_3°$, was found by Paulson[1] to occur several times among the prominent lines. The metastable $5d$ terms are at about 10,000 cm^{-1}. $^7D°$ was not found probably because most of its combinations with ^9P and ^7P lie beyond the observed region in the red. The height of $5d$ above $6s$ indicates $4f\ ^76s^2$ as the normal configuration of Eu I. The locating of the $7s$ levels enables the calculation of an ionization potential of 11.4 volts for Eu II. Three levels

[1] Kayser, Handbuch der Spectroscopie **7**, no. 1.