neutrons emerging that were elastically scattered p times may be determined:

$p=0$: 71 percent
$p=1$: 25 percent
$p=2$: 4 percent.

Those scattered once and twice will have a greater probability of detection and the increase on the total number of detector counts was roughly 0.25×1.2 percent $+0.04\times1.5$ percent (allowing a greater correction for double scattering) or 0.36 percent. This increase in the detector counts caused the inelastic cross section to be low by the increase divided by the number of inelastic mean free paths, 0.36/0.27 percent, or about 1.3 percent. Since the statistical error is 3.3 percent this correction is hardly significant.

The correction for the heavier nuclei is less, due to the greater forward peaking of the elastically scattered neutrons.

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Neutron-Deficient Cesium Isotopes*

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The new isotopes Cs^{127} and Cs^{129} have been produced from iodine by irradiation with high energy helium ions. Their mass assignments were determined with a mass spectrograph. Cs^{127} decays with 5.5 ± 0.5 hr. half-life with emission of positrons (1.2 Mev maximum energy), giving rise to the daughter activity 34-day Xe^{127}. Cs^{129} decays by electron capture with half-life 31 ± 1 hr. A 30-min. activity, presumed to be Cs^{130}, was also produced, but its mass assignment is uncertain.

THE successful completion of a thermally ionizing mass spectrograph in this laboratory and the availability of high energy helium ions from the Berkeley 184-in. cyclotron have led us to investigate neutron-deficient isotopes of alkali metals, which are relatively easy to ionize. Some results for rubidium isotopes have already been reported.[1] This paper is concerned with two new cesium isotopes.

The cesium isotopes of mass 131 and greater have been studied extensively.[2] The only report of lighter isotopes seems to be a 30-min. period produced from iodine with helium ions, presumably of 16 Mev energy from the Purdue University cyclotron.[3]

IODINE BOMBARDMENTS

Stable I^{127} (100 percent abundance) was bombarded in the form of ammonium iodide with 60-Mev helium ions in the Berkeley 184-in. cyclotron for periods of from one to four hours. The ammonium iodide was wrapped in 0.001-in. aluminum foil and irradiated mounted on a water-cooled copper block on the cyclotron probe. Elemental iodine sealed in a platinum capsule was also bombarded. Ammonium iodide was also bombarded with 36-Mev helium ions from the Crocker 60-in. cyclotron.

The cesium radioactivities induced were isolated from the target material by chemical procedures[4] designed to remove Xe, I, Te, Sb, Sn, and most other elements except alkali metals. Carrier cesium was added in some cases, but it was found that very little could be tolerated in samples destined for the mass spectrograph. It was found that sufficient Cs^{133} to serve as a reference line on the mass spectrum was provided

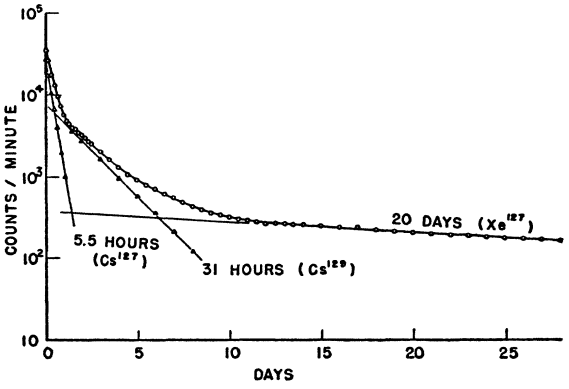

FIG. 1. Decay curve of cesium radioactivities induced by 60-Mev helium ions from ammonium iodide. The points at high counting rates were derived from data obtained at a lower geometry.

* This work was supported by the AEC.

[1] Reynolds, Karraker, and Templeton, Phys. Rev. **75**, 313 (1949).

[2] For references, see G. T. Seaborg and I. Perlman, "Table of isotopes," Rev. Mod. Phys. **20**, 585 (1948); also, Yaffe, Kirsch, Standil, and Grunlund, Phys. Rev. **75**, 699 (1949); N. Sugarman, Phys. Rev. **75**, 1473 (1949); J. L. Meem and F. Maienschein, Phys. Rev. **76**, 328 (1949); and J. S. Osoba, Phys. Rev. **76**, 345 (1949). The assignment of the 10-day cesium to mass 131 has now been confirmed with the mass spectrograph by Karraker, Reynolds, and Templeton, UCRL Report-285 (February 11, 1949) (to be published).

[3] "J. R. Risser and R. N. Smith, private communication from K. Lark-Horowitz," quoted from G. T. Seaborg and I. Perlman, reference 2.

[4] For details, see R. W. Fink, M.S. thesis, University of California, Berkeley, 1949.

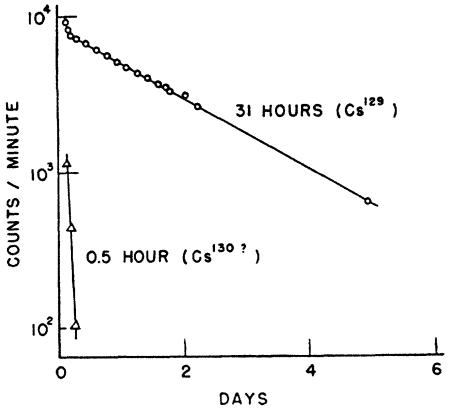

FIG. 2. Decay curve of cesium radioactivities induced from ammonium iodide by 36-Mev helium ions.

by 0.1 μg. Although the first chemical technique yielded sufficient cesium activity for all experimental purposes except mass spectrograph work, it was found that ignition of cesium chloride in an open dish to remove ammoium salts resulted in serious loss of cesium due to the high volatility of CsCl.

To prevent this loss and thereby isolate sufficient cesium activity for mass spectrograph runs, the ammonium iodide was decomposed in moderate vacuum by gentle heating with a drop of nitric acid and a few drops of sulfuric acid. A cold finger cooled with carbon dioxide snow near the sample condensed the iodine and water which escaped. Within three minutes the residue solution could be removed, containing most of the cesium activity and relatively little of the target material. This procedure resulted in substantially better yields of activity.

CESIUM RADIOACTIVITIES

In Fig. 1 is shown the decay curve for the cesium radioactivity from a 60-Mev alpha-bombardment of ammonium iodide. The sample, mounted as cesium chloride and covered with cellulose tape, was counted with an argon-alcohol Geiger tube. The decay curve is resolved into 5.5-hr., 31-hr., and 20-day components. When the chemical procedure was completed rapidly enough, a half-hour period was also observed. With 36-Mev helium ions, only the half-hour and 31-hr. activities were observed in the decay curve, Fig. 2.

After the 5.5-hr. cesium was dead, a portion of the cesium was redissolved, boiled to expel xenon, and evaporated on a counting disk. In Fig. 3 are compared the decay curves of such a sample and a portion which was not disturbed. The 31-hr. activity is not affected by this procedure. The removal of the long 20-day activity by boiling suggested that it is a xenon daughter of the 5.5-hr. cesium. It cannot be the daughter of 31-hr. cesium.

To establish the identity of the long-lived activity, a mixture of freshly isolated 5.5-hr. and 31-hr. cesium activity was placed in a small vacuum line equipped with several glass bulbs. The system was evacuated and the sample was isolated from the pumps and the bulbs. One bulb at a time was opened and cooled with liquid nitrogen, while the sample was heated. Glass wool and loops in the connecting tubing acted as a safeguard against mechanical transfer of non-gaseous material. The bulb was then sealed off and mounted on a holder for counting. The first bulb filled exhibited 109 counts/minute of activity; the walls were too thick for observation of soft radiations. This activity decayed for six weeks with a half-life of 30 to 35 days. Other bulbs filled after the 5.5-hr. activity was dead yielded no observable activity.

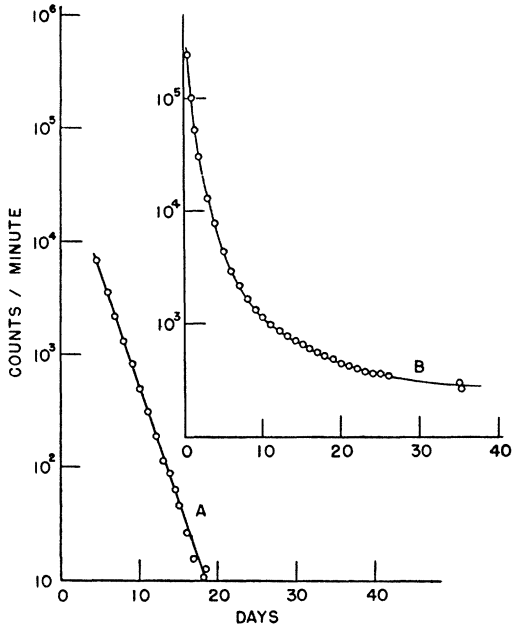

FIG. 3. Effect of repurification. Decay curve A is for a sample from which xenon was expelled by boiling from a solution after the 5.5-hr. cesium was effectively dead. Curve B is for a cesium sample which was not disturbed.

This experiment was repeated twice with similar results. On the basis of these observations, the long-lived activity is identified as the 34-day xenon[5] assigned to Xe^{127}, produced by decay of the 5.5-hr. cesium. Xe^{127} is reported to emit a 0.9-Mev gamma-ray, which is the activity counted in the glass bulb. The shorter half-life observed in cesium samples is caused by diffusion of xenon through the cellulose tape covering the sample.

MASS-SPECTROGRAPHIC EXPERIMENTS

In our mass spectrograph the sample is placed as a solid on a tungsten or platinum filament and is ionized by heat. The efficiency of the ionization for cesium has been found to be strongly dependent on the chemical

[5] Creutz, Delsasso, Sutton, White, and Barkas, Phys. Rev. **58**, 481 (1940); M. Camac, Plutonium Project Report CC-2409 (October, 1944); Overstreet, Jacobson, Scott, and Hamilton, Plutonium Project Report CH-379 (December 1942).

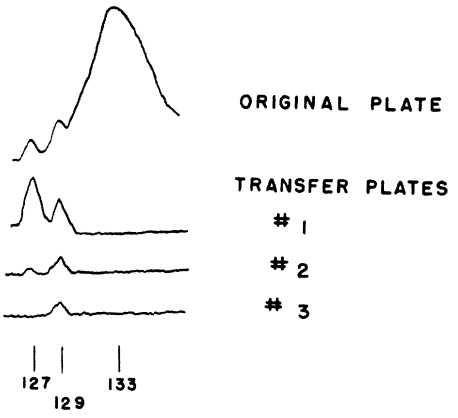

FIG. 4. Microphotometer tracings of mass spectrograph plates. Transfer plate 1 was exposed to the original plate, emulsion to emulsion, immediately after removal from the mass spectrograph, and remained on for 24 hr. Transfer 2 was exposed for the next 48 hr. Then transfer 3 was exposed approximately the next 72 hr.

state of the sample. Similar effects have been noted for some other elements, such as barium and thallium. If the photographic plate is replaced by an electrometer receiver, an integration of the current is a measure of the number of atoms ionized and passed by the slits of the apparatus. The ratio of the amount of sample placed on the filament to the amount found with the electrometer is called the "loss factor."

Experimental values for three cesium salts are listed in Table I.

Since the geometrical loss factor on the mass spectrograph is of the order of 50, with cesium sulfate at least 25 percent of the cesium is ionized. One expects 100 percent ionization under optimum conditions, because of the very low ionization potential (3.87 volts) of cesium. The very low ionization of the chloride and nitrate salts is probably due to greater volatility in vacuum. The presence of ammonium salts or other foreign matter operates to lower the ionization efficiency by increasing mechanical loss of chunks of material from the platinum filament. Only by increasing the yield of activity by use of the vacuum sublimation procedure combined with especial care to prepare practically weightless samples of the sulfate of the radioactive cesium isotopes, instead of the chloride used in early experiments, were successful mass spectrograph results finally attained.

Mass spectrograph plates showing dark lines at mass numbers 127, 129, and 133 (stable carrier) were obtained, and transfer plates showed the radioactivity of lines 127 and 129; after the 5.5-hr. Cs^{127} activity had

TABLE I. Loss factors of various cesium salts on the mass spectrograph.

Salt	Loss factor
Cesium nitrate, $CsNO_3$	1.4×10^6
Cesium chloride, CsCl	8.3×10^4
Cesium sulfate, Cs_2SO_4	180

effectively decayed out, the radioactive line at mass 129 still gave good transfer plates. This is shown in Fig. 4 which consists of microphotometer tracings of an original mass spectrograph plate and three transfer plates made at designated times after bombardment.

RADIATIONS OF 5.5-HR. Cs^{127}

A crude magnetic spectrometer and absorption methods were used to examine the radiations from Cs^{127} and Cs^{129}. Positrons were found with maximum energy about 1.2 Mev. The activity of these positrons decayed with a 5.5-hr. half-life. Lead absorption curves showed 0.5-Mev gamma-rays due to annihilation but no harder gamma-rays. Softer gammas may have been present. Negative electrons of energy of the order of 0.3 Mev and x-rays were also present, but they have not been proved to belong to Cs^{127}.

RADIATIONS OF 31-HR. Cs^{129}

No positrons were observed for Cs^{129}, and it very likely decays entirely by electron capture. It emits 0.3-Mev conversion electrons, K and L x-rays, and gamma-rays of about 0.5 Mev.

RADIATIONS OF THE 30-MIN. CESIUM

We have little data concerning the 30-min. activity. It emits x-rays and gamma-rays of the order 0.5 Mev. We have not tested it for positrons or negative electrons. Its production with 16-Mev helium ions[3] implies that it is Cs^{130}. Our data are consistent with that assignment. Cs^{128} has not been observed, but its half-life must be 30 min., or less. It is conceivable that our 30-min. activity is in part due to Cs^{128}.

ACKNOWLEDGMENTS

We wish to express our sincere appreciation to James T. Vale and B. Rossi and the crews of the 184-in. and 60-in. cyclotrons; to D. G. Karraker, for operation of the mass spectrograph on many night runs; and to Lieselotte K. Templeton, for microphotometer tracings of the mass spectrograph plates.