Alder *et al.*, and those of Liebson, using the distances shown in the latter's curves. However, these distances correspond to distances between the ends of the cathodes. Since the discharge in each counter is not limited to the cathode length, but extends along the anodes beyond the cathodes, these distances do not represent the absolute distance between the effective counters. Rough measurements on the spread of the discharge along the wire beyond the cathode indicated that the effective absolute distances would be decreased by about 1 cm. The difficulty of accurately defining this distance and its comparative irrelevance in determining the slopes of the probability curves was responsible for omitting the absolute distances from the data.

On the other hand, the measurements of Alder *et al.* are not suitable for comparison with results using organic vapors and inert gas. Their mixtures consisted of 1.5 cm Hg of argon plus 6.5 cm Hg of air and small admixtures of alcohol. The large amount of air contamination renders the extrapolation of their measurements to alcohol-argon counters questionable. Furthermore, no allowance was made for the fact that the addition of alcohol vapor to the argon-air counters may have reduced the number of photons produced. This would effectively produce a decrease in the number of quanta propagated across the 11-cm gap, acting as though an increase in absorption had taken place.

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[2] Alder, Baldinger, Huber, and Metzger, Helv. Phys. Acta 20, 73 (1947).
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Artificial Collateral Chains to the Thorium and Actinium Families

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We have produced and identified two new series of alpha-particle emitting radioactive elements; one is a "collateral" branch of the actinium ($4n+3$) radioactive family and the other is collateral to the thorium ($4n$) family. The series are of considerable interest in that they are the first whose early members lie on the neutron deficient side of beta-stability. They have been produced in high yield by irradiation of thorium with deuterons of energy about 80 Mev in the Berkeley 184-inch cyclotron. So far as the present observations are concerned, both of these series begin with isotopes of protactinium (atomic number 91), although progenitors with higher atomic numbers are to be expected and will possibly be produced and identified. These protactinium isotopes are Pa^{227} and Pa^{228} formed by $d,7n$ and $d,6n$ reactions, respectively.

After bombardments of the order of one-half to four-hour duration, the metallic thorium was dissolved and the element protactinium was isolated in essentially weightless fractions. The decay of the alpha-particles from these was measured both through the use of standard alpha-particle counting devices and also with the help of an alpha-particle pulse analyzer[1] equipped with a fast sample-changing mechanism. Through the use of the latter, a number of alpha-particle groups were observed and their energies determined.

Table I.

Isotope	Type of radiation	Half-life	Energy of radiation (Mev)
$_{91}Pa^{227}$	α	38 min.	6.46
$_{89}Ac^{223}$	α	~2 min.	6.64
$_{87}Fr^{219}$	α	$\sim 10^{-4}$ sec.	7.30
$_{85}At^{215}$	α	$\sim 10^{-4}$ sec.	8.00
$_{83}Bi^{211}$(Ac*C*)	α(99.7%)	2.16 min.	6.62
$_{81}Tl^{207}$(Ac*C''*)	β^-(0.3%)	4.76 min.	1.47
$_{82}Pb^{207}$	stable		
$_{91}Pa^{228}$	α	22 hr.	6.09
$_{89}Ac^{224}$	α	~2.5 hr.	6.17
$_{87}Fr^{220}$	α	~30 sec.	6.69
$_{85}At^{216}$	α	$\sim 10^{-3}$ sec.	7.79
$_{83}Bi^{212}$	α(34%)	60.5 min.	6.05
	β^-(66%)		2.20
$_{81}Tl^{208}$(Th*C''*)	β^-	3.1 min.	1.82
$_{84}Po^{212}$(Th*C'*)	α	3×10^{-7} sec.	8.78
$_{82}Pb^{208}$	stable		

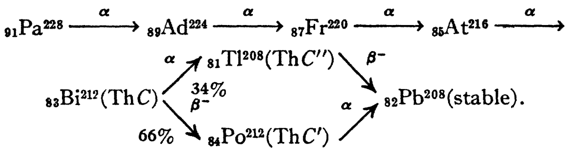
Prominent soon after bombardment are a number of alpha-particle groups, which decay with the 38-minute half-life of the protactinium parent. These are due to the following collateral branch of the $4n+3$ radioactive family:

$$_{91}Pa^{227} \xrightarrow{\alpha} {}_{89}Ac^{223} \xrightarrow{\alpha} {}_{87}Fr^{219} \xrightarrow{\alpha} {}_{85}At^{215} \xrightarrow{\alpha}$$
$$_{83}Bi^{211}(AcC) \xrightarrow{\alpha} {}_{81}Tl^{207}(AcC'') \xrightarrow{\beta^-} {}_{82}Pb^{207}(\text{stable}).$$

The branch which arises from orbital electron capture by Pa^{227} is not shown. The mass type was identified by observation of the characteristic energy and half-life of the Bi^{211}(Ac*C*) alpha-particles, the half-life of the beta-particle emitting Tl^{207}(Ac*C''*), and the growth of 18.9-day Th^{227}(RdAc) as an orbital-electron-capture branching decay product of the Pa^{227} (ratio $K/\alpha = \sim 0.2$). The energy obtained for these At^{215} alpha-particles is several hundred kilovolts less than that reported[2] for At^{215} as formed by the beta-particle branching decay of Po^{215}(Ac*A*).

Identification of members of the series was aided by a simple method of recoil collection. Recoil atoms were collected from a plate which contained the entire series in equilibrium and measurements using the plate upon which these were collected established the half-life and the energy of the Ac^{223} alpha-particles. In a "second-order" recoil experiment recoils were collected from the plate containing Ac^{223} (and daughters) in order to check the half-life of the alpha-particles attributed to Bi^{211}(Ac*C*) and similarly a third-order recoil experiment was effected in order to isolate the beta-particle emitter and prove that it decayed with the known half-life of Tl^{207}(Ac*C''*). The very short half-lives of the Fr^{219} and At^{215} were estimated, and their energies identified through crude coincidence experiments using the pulse analyzer apparatus to operate the driven sweep of a cathode-ray oscillograph. The measured half-lives and energies for the members of this series are summarized in Table I.

After the decay of the above-described series, a second group of alpha-particle emitters can be resolved. This second series, which decays with the 22-hour half-life of its protactinium parent, is a collateral branch of the $4n$ radioactive family as follows:



The branch which arises from orbital electron capture by Pa^{228} and Ac^{224} is not shown. The mass type was identified through observation of the characteristic radioactive properties of the Bi^{212}(ThC) and its daughters, chemical identification of Bi^{212}(ThC), the growth of Th^{228}(RdTh) as an orbital-electron-capture branching decay product of the Pa^{228} (ratio $K/\alpha = \sim 50$) and the growth of Ra^{224}(ThX) as a similar product of the Ac^{224} (ratio $K/\alpha = \sim 10$). Of interest is the check, within about 0.15 Mev, of the energy of these At^{216} alpha-particles with the energy reported[3] for At^{216} as formed by the beta-particle branching decay of Po^{216}(ThA). The half-life of the Ac^{224} could be measured and the energy of its alpha-particles identified as the result of its collection in recoil experiments. Similarly, the half-life and alpha-particle energy of the Fr^{220} could be determined by second-order recoil experiments from plates containing only Ac^{224} (and daughters). The very short half-life at At^{216} was estimated as described above and its energy could be determined by measurements on samples containing its progenitors. The half-lives and energies are summarized in Table I. The radioactive properties of ThC (and AcC) and daughters are the accepted values taken from the literature.[4]

These data extend the information on the isotopes of protactinium, actinium, francium, and astatine so that more interesting correlations[5] of mass and atomic numbers, etc., with alpha-particle decay energies and half-lives are possible.

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The Half-Life of C^{14}

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FROM experiments which have recently been described,[1] Norris and Inghram conclude that the half-life of C^{14} is 5100 years; earlier experiments[2] by the same authors had given somewhat higher values, namely, 6100 and 5300 years, the former being, however, a preliminary value. A value of 4700 years was obtained by Reid, Dunning, Weinhouse, and Grosse.[3]

Experiments have also been carried out in the standardization laboratory of this project for the purpose of providing C^{14} standards. With this end in view the activity of C^{14} in samples of carbon dioxide has been measured in gas counters similar to those which have been described by Miller.[4,5] In order to eliminate possible errors arising from end effects, compensated counter units each consisting of a long and a short copper cathode of the same radius and having as nearly similar end geometries as possible have been used. To investigate the errors which might arise on account of β-particles entering the wall from a thin layer of gas at the wall and not giving rise to a pulse, experiments were carried out using compensated counter units of different radii and with fillings at different pressures. The counters were quenched by means of a Parkinson multivibrator quenching unit.[6]

The results obtained assuming a 100 percent counter efficiency, in conjunction with a mass-spectrometer, isotope-abundance determination, lead to a value for the half-life of C^{14} of 6400 ± 200 years.

Further experiments are to be carried out to check the efficiencies of the counters, but the investigation into the effect of radius referred to above would indicate that the counters are not less than 95 percent efficient. Such an efficiency would correspond to a half-life of 6100 ± 200 years, which is still considerably higher than that obtained by Norris and Inghram.

We wish to acknowledge with thanks the help which we have received from Mr. G. B. Parkinson and Mr. F. N. MacGillivray. We also wish to express our thanks to Professor H. Thode of McMaster University for placing at our disposal the facilities of his laboratory, and to Mr. C. Collins who operated the mass spectrometer. A more detailed account of these experiments together with a description of the preparation of the active carbon is to be submitted for publication in the near future.

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The Half-Life of C^{14}

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THE half-life of C^{14} has recently been checked by several investigators. Values found were 4700[1] and 5100[2] years. Hawkings, Hunter, Mann, and Stevens[3] have, by mass spectrographic analysis and gas counting, obtained a value of 6400 ± 200 years.

Since this last value was so much higher than the previously accepted values, it was decided to check this using a calibrated end-window Geiger counter. We used an aliquot of the same Na_2CO_3 solution used by Mann *et al.* from which they generated CO_2. The samples were mounted on very thin (50 $\mu g/cm^2$) Formvar films. Correc-