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RECENT STUDIES OF THE ISOTOPES OF EMANATION, FRANCTUM, AND RADIUM

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Authors
Momyer, F.F.
Hyde, E.K.
Ghiorso, A.
et al.

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F. F. Momyer, E. K. Hyde, A. Ghiorso, and W. E. Glenn
Radiation Laboratory and Department of Chemistry
University of California, Berkeley, California

March 19, 1952

Berkeley, California
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An earlier study\(^1\) of the alpha decay characteristics of the low mass isotopes of francium and emanation produced by bombardment of thorium with 340 Mev protons for the purpose of correlating these characteristics with the 126 neutron shell has been continued and expanded to include the element radium.

Greatest progress has been made in the case of emanation where the properties listed in Table I have been measured.

Table I. Radioactive properties of low mass emanation isotopes.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Observed half-life</th>
<th>Alpha particle energy</th>
<th>EC/alpha branching ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Em(^{209})</td>
<td>3 min</td>
<td>6.02</td>
<td>4-6</td>
</tr>
<tr>
<td>Em(^{210a})</td>
<td>2.7 hr</td>
<td>6.02</td>
<td>~0.1</td>
</tr>
<tr>
<td>Em(^{211})</td>
<td>16 hr</td>
<td>5.82</td>
<td>2.8</td>
</tr>
<tr>
<td>Em(^{212})</td>
<td>23 min</td>
<td>6.23(^b)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

\(^a\)This isotope is to be identified with the 2.1 hr activity reported by Ghiorso, et al.\(^2\)

\(^b\)This value supersedes that given by Hyde, et al.;\(^1\) also the Fr\(^{212}\) alpha particle energy should be raised to 6.36 Mev.

*This work was performed under the auspices of the AEC.

**Part of this material was presented at the XIIth International Congress of Pure and Applied Chemistry, New York City, September, 1951.
This work was greatly facilitated by the development of a method for the preparation of platinum plates with the emanation atoms so firmly affixed that counting techniques typical for non-gaseous radioactive samples could be employed. In brief, this method consisted of ionization of the gaseous atoms in a glow discharge and acceleration of these ions into a platinum plate at a potential of a few hundred volts. The method is being applied successfully to krypton and xenon as well as emanation and should be widely applicable in nuclear studies of the nuclides of these elements. This technique resembles that reported by Bergström, et al.\(^3\) in the study of mass-spectrographically separated radioactive isotopes of rare gas elements.

It is interesting to note that a plot of the alpha decay energies for the emanation isotopes against neutron number is strikingly similar to the corresponding plot for the isotopes of polonium and astatine as shown in Fig. 1. The alpha decay energy of \(\text{At}^{211}\) is given as 5.96 Mev (alpha particle energy, 5.85 Mev) to correspond with a recent redetermination by us.

Many experiments were performed to obtain information on francium isotopes other than \(\text{Fr}^{212}\) in this mass region. In this work carrier free francium fractions were isolated from thorium target solutions by an improved method developed by Hyde.\(^4\) Any isotopes of half-life greater than 5 minutes would have been identified easily. It can be stated that the apparent half-lives of \(\text{Fr}^{213}\), \(\text{Fr}^{211}\) and isotopes of mass less than 211 are all shorter than 5 minutes. Incomplete results indicate a half-life of 2-5 minutes for \(\text{Fr}^{211}\), with electron capture prominent.

Mass assignments in the genetically-linked \(\text{Fr}^{212}-\text{Em}^{212}-\text{At}^{208}-\text{Po}^{208}\) system were made certain by a mass spectrographic assignment of the key nuclide, \(\text{Fr}^{212}\). This was done with the time of flight mass spectrometer
Attempts were made to isolate chemically radium isotopes of mass 214 or less and thus prove that the shell effect extended to this element. However, the stabilization was expected to lengthen the alpha decay half-lives to the order of only a few minutes. Evidence was found for the following sequence:

\[
\begin{align*}
\text{Ra}^{213} & \xrightarrow{a} \text{Em}^{209} \xrightarrow{\text{EC}} \text{At}^{209} \\
\text{2 min} & \xrightarrow{a} \text{Po}^{205}
\end{align*}
\]

The Ra\(^{213}\) was not observed directly because of its short half-life and because of the interference from heavier radium isotopes.

Cross checks are being carried out using a quite distinct method of preparation of the nuclides; namely, the bombardment of lead foils with carbon ions. Miller, et al.\(^6\) have recently reported the attainment of a sizable beam of energetic (>100 Mev) \(C^+\) ions in the Crocker Laboratory 60-inch cyclotron and have effected such reactions as \(\text{Au}^{197}(C^{12},4n)\text{At}^{205}\). For our purposes bombardment of lead foils produces radium isotopes of mass 216 or less by such reactions as \(\text{Pb}^{208}(C^{12},4n)\text{Ra}^{216}\). These directly produced radium isotopes decay quickly by alpha particle emission or electron capture to the emanation and francium isotopes in which we are interested. An outstanding advantage of this method, particularly for Ra\(^{213}\), is that none of the higher mass isotopes of these elements can possibly be produced and hence the interference from them is not present.

As a by-product of the studies of the emanation fraction from the thorium plus proton bombardments, some properties of the previously unreported Em\(^{221}\) were observed. The gaseous fraction from the dissolution of a thorium foil target bombarded with 100 Mev protons was purified and placed on a platinum
plate using the glow discharge collection technique. This plate when examined in the alpha ray pulse analyzer showed the alpha particle peaks corresponding to 4.8 minute Fr$^{221}$ and its 0.020 second daughter At$^{217}$. Later the expected growth and decay of the Po$^{213}$ alpha peak were observed. The Fr$^{221}$-At$^{217}$ double peak decayed with a half-life of 20 minutes. These facts can be interpreted only as meaning that Em$^{221}$ is a beta emitter of 20 minutes half-life. The alpha branching is appreciable and is currently under investigation.

This work is continuing and a complete report will be issued later.

We wish to acknowledge the assistance of J. T. Vale, L. B. Houser, and the 184-inch cyclotron crew in carrying out the high energy proton bombardments. Thanks also are due G. B. Rossi for assistance in the carbon ion bombardments.

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Similarity of shell effect in elements 84-86 shown by plot of alpha decay energy versus neutron number.