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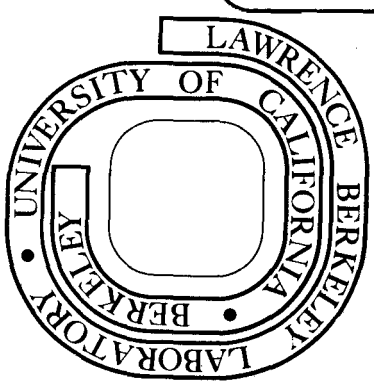

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DISCLAIMER

ISOMERIC STATES IN ^{212}Bi

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Abstract

Two new alpha activities with half-lives of 25 min and 9 min have been observed in reaction of heavy ions with a variety of heavy targets. The 25 min activity was found by combined radiochemical methods and mass separations to be an isomer in ^{212}Bi; the 9 min activity is also likely to be an isomer in ^{212}Bi.

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During a search for superheavy elements via the reaction of ^{48}Ca with ^{248}Cm, we observed several alpha lines around 10.2 MeV.[1] In addition a rather intense line at 11.6 MeV was observed and attributed to the known isomer in ^{212}Po.[2] A closer investigation of the 11.6 MeV peak through analysis of its decay curve revealed a longer lived component of 9±1 min, in addition to the expected 46 sec half-life. The half-life of the alpha group at 10.2 MeV was determined to be 25±1 min. We eliminated the possibility that these activities could be associated with the decay of superheavy elements when these activities were found in a bombardment of ^{208}Pb with ^{40}Ar ions.

After preliminary experiments showed that the activities were coprecipitated with CuS from an acidic solution and taking into account the high energy associated with their decay,

these activities were presumed to be nuclides in the lead region. Further studies revealed that both activities could be produced by the bombardment of ^{238}U targets by a variety of heavy ions such as ^{40}Ar, ^{48}Ca, and ^{136}Xe. The reaction of ^{40}Ar with ^{238}U was chosen for subsequent work due to the availability of intense beams and target material.

Intense sources containing both activities were produced by irradiating thick targets of depleted uranium (^{238}U) with ^{40}Ar ions from the SuperHILAC or the 88-inch cyclotron. The targets were electrolytically dissolved down to the maximum recoil range in a mixture of nitric and hydrochloric acids. The target solution was heated to remove the nitric acid before adjusting the pH to 2.5±0.5 with NaOH. To this solution 0.5 ml of 0.1% solution of diphenylthiocarbazone (DTZ) in CCl_4 was added and the phases were equilibrated for 1-2 minutes using a vortex mixer. Under these conditions, Bi, Po and At were extracted into the organic phase and a separation of the order of 95% from Pb was achieved. After centrifugation the DTZ solution was evaporated onto a platinum disk which was gently flamed. This procedure yielded weightless alpha sources of total activity several times 10^5 dpm consisting mostly of ^{212}Bi-^{212}Po, ^{213}Bi-^{213}Po, ^{214}Bi-^{214}Po, and the new activities. A spectrum is shown Fig. 1. An intense doublet at 6.297 and 6.336 MeV was noted to decay with a 25 minute half-life and is believed to be associated with the 10.2 MeV alpha group. All other lines

in the spectrum could be explained in terms of known activities.

The chemical identification of the 25 minute activity was accomplished through the technique of residue adsorption or chemisorption.[3] This method is based on the self-deposition of certain elements on noble metal surfaces followed by selective desorption by an appropriate solvent. The alpha spectra of the various fractions separated by chemisorption proved unequivocally that this activity follows the chemistry of Bi. Due to the small amount of the 11.6 MeV activity and its short half-life, this activity was not chemically identified by this procedure.

Three successful isotope separation experiments were performed with the LBL Isotope Separator on a sample obtained with the DTZ extraction. The results showed that both the intense doublet and the 10.2 MeV group are associated with the mass number 212. Again due to the short half-life and low yield, the 11.6 MeV activity was not identified as to its mass number. The alpha spectra of the mass separated samples are shown in Fig. 2.

The chemical separation together with the mass separation indicate that at least the 25 minute activity can be associated with an isomeric state in ^{212}Bi. Our studies further indicate the 25 minute isomeric state, $^{212ml}Bi$, decays both by alpha emission to ^{208}Tl and by beta emission to excited levels of ^{212}Po followed by the emission of "long-

range" alpha particles to the ground state of ^{208}Pb. The energy equivalence of the 11.6 MeV activity with the unique transition in ^{212m}Po suggests that this activity results from the beta decay of a second isomeric state in ^{212}Bi to the 46 second ^{212m}Po. A decay scheme based on this working hypothesis is shown in Fig. 3.

The assignment of the 25 minute activity is supported by a comparison with the ground state decay of ^{212}Bi. The ground state of ^{212}Bi (1^-) is known to alpha decay to the ground and first excited state of ^{208}Tl yielding two alpha lines separated by 40 keV.[4] Beta decay also occurs from this state to the ground state of ^{212}Po followed by the emission of alpha particles to the ground state of ^{208}Pb. In addition a small beta decay branch to low-spin excited states of ^{212}Po exists followed by the emission of "long-range" alphas. The 25 minute activity exhibits similar behavior in that two alpha lines are observed which are separated, within experimental error, by 40 keV. If it is assumed that the 6.336 MeV line results from a transition to the ground state of ^{208}Tl, the energy of the isomeric state would be 250 keV. Our interpretation of the 10.2 MeV group as "long-range" alphas emitted from levels of ^{212}Po following the beta decay of $^{212ml}Bi$ is supported by the shape of the alpha lines in spectra taken at high geometry. The slope of the high energy side of the 10.2 MeV lines indicates that a beta particle was emitted simultaneously with the emission of the alpha particle within the

resolving time of the equipment. This effect is visible in both the ^{212}Po ground state transition and the 10.2 MeV group in the spectrum of the mass separated sample, Fig. 2.

The fact that an isomeric state should exist in ^{212}Bi is suggested by analogy with the 9^- isomeric state in ^{210}Bi.[5-8] The configuration of ^{212}Bi, $(\pi h_{9/2})(\nu g_{9/2})^3$, differs from that of ^{210}Bi, $(\pi h_{9/2})(\nu g_{9/2})$, in that ^{212}Bi has two additional $g_{9/2}$ neutrons. Shell-model studies have been carried out on the ground state and low-lying states of the configuration $(\pi h_{9/2})(\nu g_{9/2})$ of ^{210}Bi by Kim and Rasmussen.[9] Their calculations which are in excellent agreement with the experimental observations of Motz et al.[10] indicate the level responsible for the isomeric state is a 9^- state located at 268 keV. Although no such shell-model calculations have been reported in the literature for ^{212}Bi, we do not believe that the addition of two neutrons coupled to zero should change considerably the corresponding level structure in ^{212}Bi. Therefore we suggest an analogous 9^- spin for the isomeric state in ^{212m1}Bi.

Detailed shell-model calculations of the excited levels of ^{212}Po have been made by several authors. In one such calculation Glendenning and Harada allowing for configuration mixing, predicted a state with $J^\pi=18^+$ to explain the 46 second ^{212m}Po.[11] Their results also indicate the possibility of another isomeric state J=10-12 at an excitation energy of 1.2 MeV. On the other hand, calculations assuming no configuration mixing by Auerbach and Talmi indicate a spin of 16 for

^{212m}Po.[12] Likewise, their calculations also suggest a second isomeric state, however, of lower spin, around J=8-10.

It is reasonable to assume that since the first excited state of ^{208}Pb is 2.6 MeV above the ground state, the 10.2 MeV group decays to the ground state of ^{208}Pb. This would place the levels in ^{212}Po responsible for the 10.2 MeV transitions at an excitation energy of 1.0 to 1.3 MeV. These levels are consistent with either of the shell-model calculations mentioned.

As a test for the assumption of a 9^- isomeric level in ^{212}Bi, one would expect a log ft value of 6-9 (first forbidden transition) for a beta decay from a 9^- to either an 8^+ or 10^+ state in ^{212}Po. Our log ft value of 7 is then compatible with the spin assignment of 9^- for $^{212m1}Bi$.

We explain the 9 minute, 11.6 MeV activity in terms of a second isomeric state in ^{212}Bi which beta decays into ^{212m}Po. By promoting the odd $g_{9/2}$ neutron to either an $i_{11/2}$ or $j_{15/2}$ shell model state and then coupling to the odd $h_{9/2}$ proton, the maximum spin states that can be obtained are a 10^- and 12^+ respectively. These states can be expected to feed either the 16^+ or 18^+ levels predicted in ^{212}Po by the shell model calculations only through states of intermediate angular momentum. However, if one breaks the neutron pair and recouples the four particles to maximum spin, a 15^- state can be obtained. The possibility of a four particle state with $J^\pi=15^-$ has been suggested independently by M. Lederer.[13]

In conclusion we have shown direct evidence for the existence of a 25 minute isomeric state in ^{212}Bi through chemical and mass identification. We believe this state is analogous to the 9^- isomeric state in ^{210}Bi. Our studies further suggest a second isomeric state which beta decays to ^{212m}Po.

Acknowledgments

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Figure Captions

Fig. 1. Alpha spectrum of the Bi, Po and At fraction from $^{48}Ca + ^{238}U$. (XBL 783-332)

Fig. 2. Alpha spectrum of the mass separated sample. (XBL783-333)

Fig. 3. Tentative decay scheme for isomeric states in ^{212}Bi. (XBL783-330)

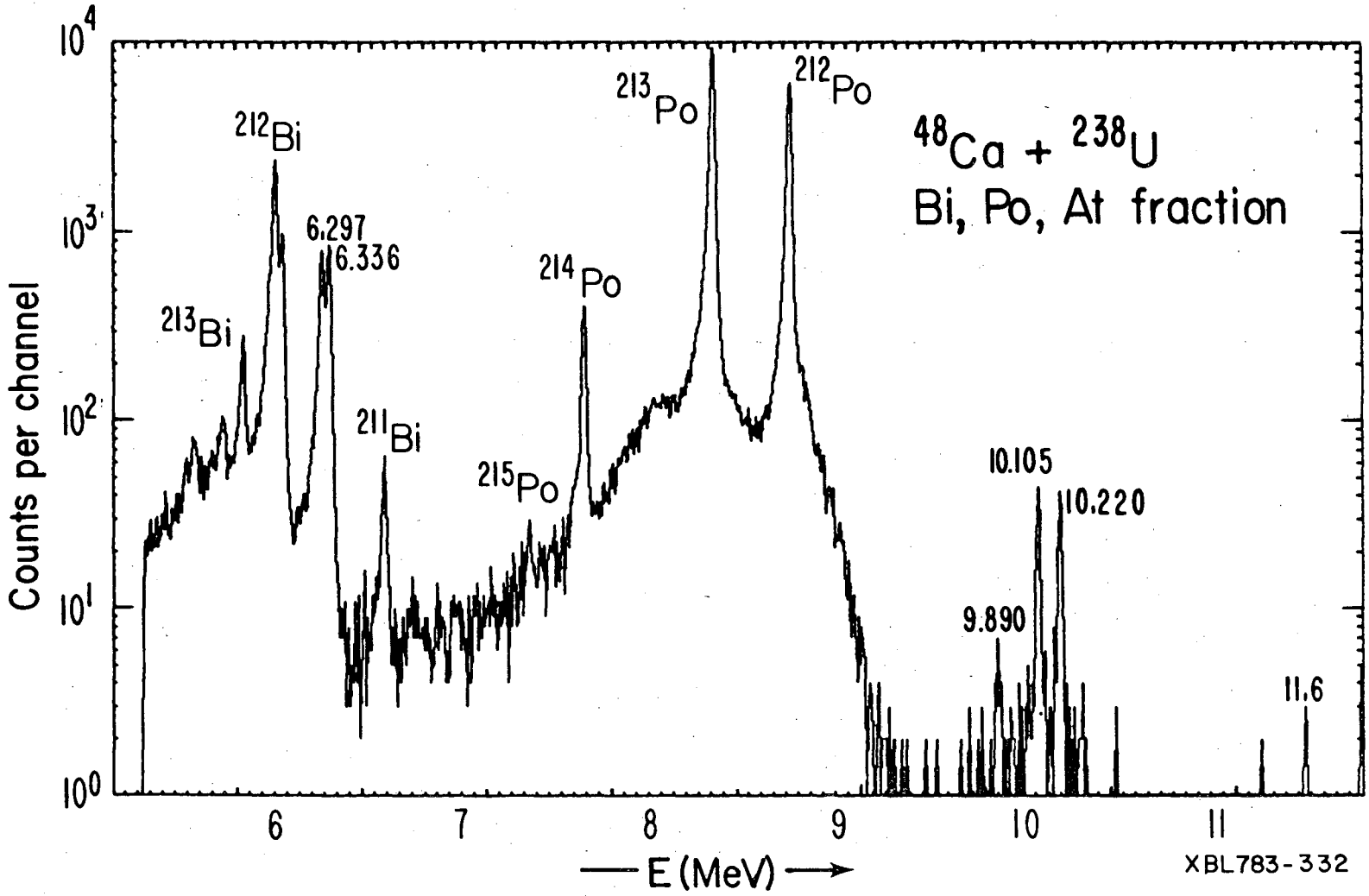
Counts per channel
10^4
10^3
10^2
10^1
10^0
^{212}Bi
^{213}Bi
6.297
6.336
^{211}Bi
^{215}Po
^{214}Po
^{213}Po
^{212}Po
^{48}Ca + ^{238}U
Bi, Po, At fraction
10.105
10.220
9.890
11.6
6
7
8
9
10
11
E (MeV)
XBL783-332

Fig. 1

MASS SEPARATED SAMPLE

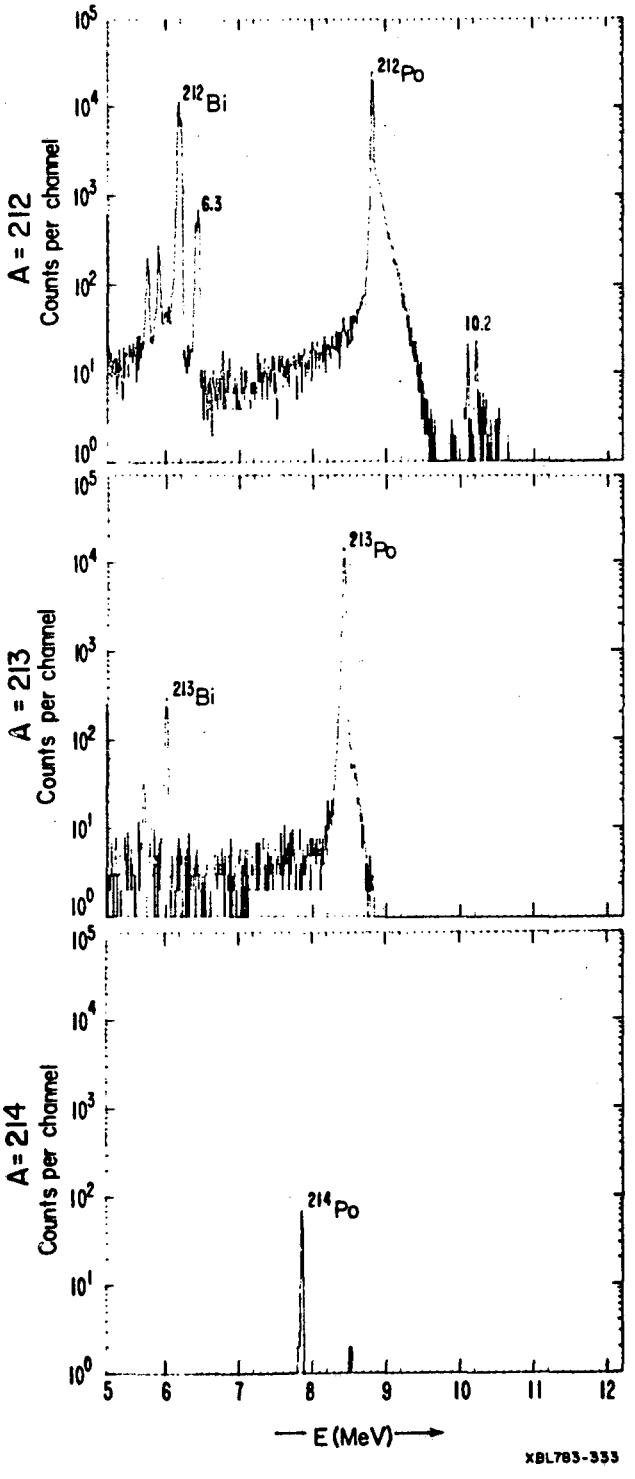

Fig. 2

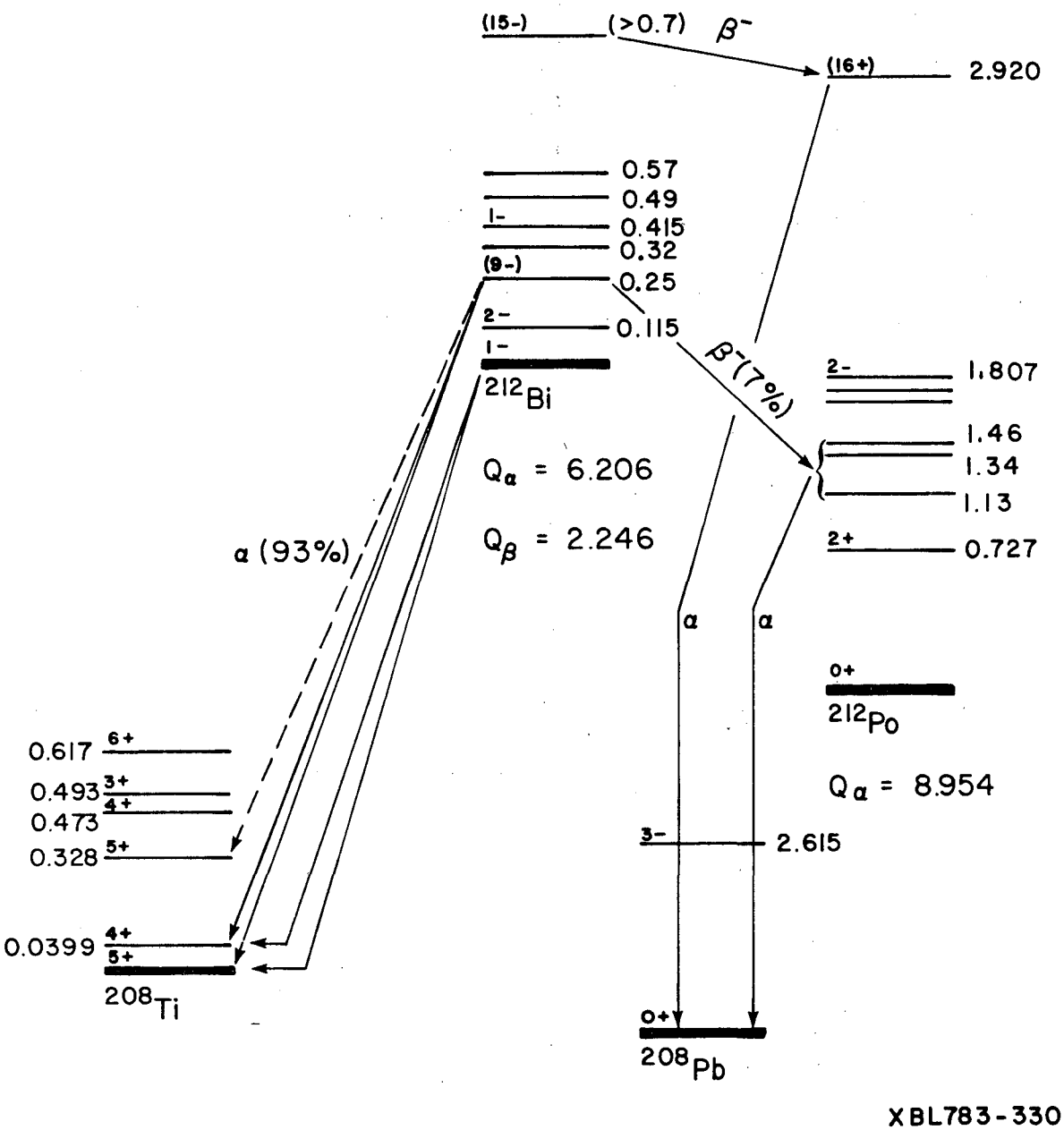
Tentative decay scheme
(15-)
(>0.7) β⁻
(16+)
2.920
0.57
0.49
1-
0.415
0.32
(9-)
0.25
2-
0.115
1-
212Bi
β⁻(7%)
2-
1.807
1.46
1.34
1.13
2+
0.727
Qα = 6.206
Qβ = 2.246
α (93%)
α
α
0+
212Po
Qα = 8.954
0.617 6+
0.493 3+
0.473 4+
0.328 5+
3-
2.615
0.0399 4+
5+
208Ti
0+
208Pb
XBL783-330

Fig. 3

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