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SECONDARY PARTICLES RESULTING FROM 375 MeV ALPHA BOMBARDMENT OF NUCLEI

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February 4, 1953

Berkeley, California

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A program[1] has been undertaken to analyze the secondary particles which result from high energy bombardment of nuclei. In the present experiment, thin targets of Be, Al, Ni, Ag, Au, and U have been bombarded by 375 Mev alpha particles of the 184-inch cyclotron. Secondary particles then spiral down into Ilford C2, 200μ nuclear track plates which are located at three positions below the median plane of the cyclotron. The description of the apparatus can be found in reference 1. The analysis of the secondary particles is similar to that found in reference 1.

Table I shows the secondary particles with which we are concerned and their mean energies in each position.

Table II shows the results obtained. Each element is normalized to 100 percent for the number of particles found per unit solid angle per unit radius of curvature interval.

The hydrogen and helium isotopes are identified individually. For the heavier isotopes, only Li^8 and B^8 could be resolved in each position. They are recognizable because of the characteristic hammer at the end of the range. Li^7 could be identified only in the 42-46 cm position. Li^6 and Be^7 form a common locus together which is separable in each position although there is possible contamination by carbon isotopes in the 21-24.5 cm position. For the remaining heavy secondary particles, there was overlapping of ranges so that separation could only be made by groups in the 42-46 cm position and the 29-32.5 cm position. Carbon was the highest atomic number considered because the range-energy relations have not been verified for higher atomic number. However, higher atomic number could possibly fall into Group II and III in the 42-46 cm position and into groups I and II in the 29-32.5 cm position.

The minimum range accepted was 9 microns. All tracks that had a range greater than 9 microns but still too short to fall on a calculated locus

were put in the "not classified" group. The resolution for the separation of the heavy isotopes decreases with energy so that in the 21-24.5 cm only Li^6 and Be^7 could be separated while all the rest fall into the "not classified" position. The 9 micron criterion eliminated very little information for the light elements but for Au and U there were many tracks which were shorter. These doubtless included fission fragments.

The analysis of the results of this experiment are still in a preliminary stage. Similar experiments are being done with the same targets but using high energy protons and deuterons as the bombarding particles. An angular distribution measurement using high energy alphas is also being made in order to separate the instantaneous emission of particles from the struck nucleus from the slow boiling off process.

The results of this experiment and reference 1 indicate that fragments of $A > 4$ are emitted from nuclei with high momenta. Dr. L. Alvarez has suggested as a possible mechanism that these heavy fragments are not created in the initial bombardment but are subsequently formed by the fission of resultant nuclei left in excited states.

I am particularly indebted to Dr. W. Barkas for his aid in guiding this entire program. I wish to thank Esther Jacobson for having scanned most of the plates.

REFERENCES

1. W. Barkas and H. Tyren, Phys. Rev. 89, 1 (1953)

TABLE CAPTIONS

Table I Mean energies of secondary particles in Mev. The target thickness in mg/cm^2 for each element was the following: Be (8.67), Al (1.67), Ni (8.10), Ag (12.8), Au (11.7), U (23.0). No correction for target thickness has been made. It is significant for particles of short range.

Table II Abundance distribution of products. Each element has been normalized to 100 percent for the number of particles found per unit solid angle per unit radius of curvature interval. The actual number of tracks found are in brackets and are listed below the percentages in each case.

MEAN ENERGY OF SECONDARY PARTICLES

Radius of Curvature Interval	42-46 cm	29-32.5 cm	21-24.5 cm
H^1	18.5	9.1	5.0
H^2	9.3	4.6	2.5
H^3	6.2	3.0	1.7
He^3	24.9	12.2	6.6
He^4	18.8	9.2	5.0
He^6	12.5	6.1	3.3
He^7	10.7	5.2	2.9
Li^6	28.2	13.8	7.5
Li^7	24.2	11.8	6.4
Li^8	21.2	10.3	5.6
Li^9	18.8	9.2	5.0
Be^7	43.0	21.0	11.4
Be^9	33.0	16.3	8.9
Be^{10}	30.1	14.7	8.0
B^8	58.8	28.7	15.6
B^{10}	47.0	22.9	12.5
B^{11}	42.7	20.8	11.3
B^{12}	39.2	19.1	10.4
C^{10}	67.7	33.0	18.0
C^{11}	61.5	30.0	16.3
C^{12}	56.4	27.5	15.0
C^{13}	52.1	25.4	13.9
C^{14}	48.3	23.7	12.9

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Table I

RADIUS OF CURVATURE INTERVAL

Element	42-46 cm						29-32.5 cm						21-24.5 cm					
	Be	Al	Ni	Ag	Au	U	Be	Al	Ni	Ag	Au	U	Be	Al	Ni	Ag	Au	U
H^1	10.92 (163)	12.10 (199)	13.36 (239)	17.37 (194)	29.62 (178)	28.74 (204)	8.36 (119)	13.57 (214)	26.88 (401)	38.56 (499)	19.59 (402)	9.79 (271)	6.50 (125)	14.82 (276)	31.16 (491)	15.30 (508)	1.67 (196)	2.45 (137)
H^2	3.62 (54)	2.43 (40)	2.63 (47)	3.40 (38)	3.16 (19)	2.26 (16)	3.94 (56)	1.97 (31)	0.87 (13)	0.15 (2)	0.09 (2)	0.33 (9)	2.08 (40)	0.65 (12)	0.19 (3)	0.06 (2)	0.14 (16)	0.25 (14)
H^3	2.75 (41)	0.48 (8)	0.34 (6)	0.09 (1)	0.17 (1)	0.42 (3)	2.32 (33)	0.19 (3)	0.34 (5)	0.15 (2)	0.09 (2)	0.25 (7)	1.51 (29)	0.43 (8)		0.03 (1)	0.08 (9)	0.15 (8)
He^3	2.68 (40)	1.46 (24)	1.29 (23)	1.07 (12)	1.16 (7)	1.13 (8)	4.29 (61)	1.33 (21)	1.01 (15)	0.08 (1)	0.15 (3)	0.47 (13)	2.76 (53)	0.59 (11)	0.38 (6)	0.06 (2)	0.17 (20)	0.27 (15)
He^4	10.52 (157)	9.67 (159)	7.88 (141)	17.46 (195)	28.29 (170)	18.60 (132)	17.19 (273)	14.97 (236)	8.51 (127)	2.24 (29)	1.17 (24)	3.87 (107)	12.59 (242)	11.70 (218)	2.22 (35)	0.25 (8)	0.49 (58)	4.01 (224)
Li^6,Be^7	0.74 (11)	0.42 (7)	0.50 (9)	0.63 (7)	1.50 (9)	1.55 (11)	0.63 (9)	1.14 (18)	0.47 (7)		0.34 (7)	0.47 (13)	0.83 (16)	0.48 (9)	0.19 (3)		0.43 (5)	0.38 (21)
Li^7	0.33 (5)	0.48 (8)	0.34 (6)	0.27 (3)	0.83 (5)	0.28 (2)												
Li^8	0.07 (1)					0.14 (1)	0.28 (4)						0.16 (3)					0.02 (1)
B^8	0.07 (1)	0.06 (1)												0.05 (1)				
I	0.27 (4)	0.42 (7)	0.06 (1)	0.27 (3)	0.17 (1)		0.77 (11)	1.46 (23)	0.47 (7)	0.38 (5)	0.68 (14)	0.43 (12)						
II	0.07 (1)	0.18 (3)	0.06 (1)	0.09 (1)	0.17 (1)	0.42 (3)	0.21 (3)	1.27 (20)	0.14 (2)	0.08 (1)	0.09 (2)	0.32 (9)						
III		0.12 (2)	0.06 (1)	0.18 (2)		0.71 (5)												
Not Classified	0.13 (2)	0.61 (10)	0.22 (4)	0.81 (9)	8.15 (49)	16.91 (120)	0.07 (1)	3.30 (52)	0.14 (2)	0.23 (3)	1.27 (26)	4.05 (112)	1.35 (26)	3.60 (67)	0.32 (5)	0.18 (6)	0.31 (37)	1.36 (76)
	I - He^6, Be^9, B^{10}, C^{11} II - Be^{10}, B^{11}, C^{12}, C^{13} III - He^7, Li^9, B^{12}, C^{14}						I - He^6, Li^7, Be^9, Be^{10}, B^{10}, B^{11}, C^{11}, C^{12}, C^{13} II - He^7, Li^9, B^{12}, C^{14}											

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Table II