Resonance Interaction Between Deuterons and Alpha-Particles

In a recent paper before the American Physical Society[1] we have presented some of the results of experiments on the scattering of alpha-particles by deuterium which show that the non-Coulombian field between the particles is confined to smaller distances of separation than it is in the case of scattering by hydrogen. A continuation of these experiments in which we investigated the precise nature of the anomalous scattering for low energies (at which the deviation from Coulomb scattering first becomes effective) shows an important difference from the scattering by protons. We suggest that this difference is due to a resonance interaction similar to those already established in disintegration experiments on heavier elements.

The experiments to be described consist in bombarding a thin layer of $Ca(OD)_2$ by alpha-particles whose range (and hence energy) can be varied by varying the pressure of gas (oxygen) between a polonium source and the target. The recoil deuterons emitted in directions close to that of the impinging alpha-particles are counted by means of a proportional Geiger counter. The results of bombarding an annular target covered first with a thin layer of $Ca(OD)_2$ and later with vaseline (containing ordinary hydrogen) under identical geometrical conditions are shown in Fig. 1

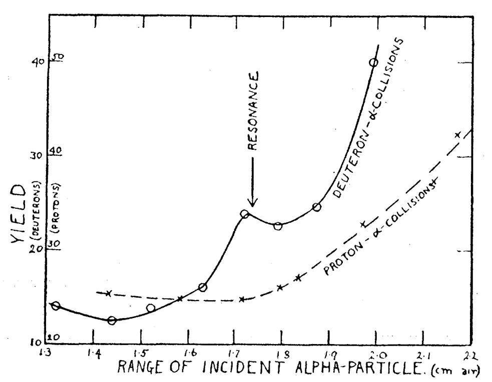

FIG. 1.

which is typical of numerous similar runs. For short alpha-particle ranges both curves show a falling yield, which is expected according to the classical theory, and both show a considerable increase for greater ranges, corresponding to anomalous scattering. The curve for protons rises smoothly in the way found by Chadwick and Bieler,[2] while that for deuterons rises more sharply, drops slightly and rises rapidly as the range of the alpha-particle increases.

According to Mott's theoretical treatment[3] the existence of an energy level in the composite nucleus (such as gives peaks in disintegration yield curves for elements like Be, N, Mg, Al) should cause a rise and fall in the yield of scattered alpha-particles. For light nuclei the effect is marked, depending on the quantity $(137/2Z)(v/c)$ (where v is the velocity of the alpha-particle) while for nuclei such as aluminum it would require extremely careful counting to be detected.

If we suppose that the incident alpha-particle in these experiments has an energy equal to that of a level in the ${}_3Li^6$ nucleus then an anomalous rise and fall would be expected, as we find it. The fact that the fall does not occur as markedly as the rise is due to the circumstance that anomalous scattering is taking place independently, so that a rise is superposed on the decreasing resonance yield. A similar superposition is apparent in the disintegration of beryllium by alpha-particles.[4]

In the case of hydrogen a resonance effect of the type here described is unlikely because it would imply the existence of a combination like ${}_3Li^5$ whose ratio of charge to mass is too great for stability.

The energy of the alpha-particles at resonance is 4.9×10^{-6} erg or 3.1 MEV. The present example appears to be the first instance of a resonance effect observed in alpha-particle scattering.

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March 14, 1935.

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The Abundance Ratio of the Isotopes of Lithium

The marked divergence existing between the mass spectrograph and the optical values for the abundance ratio of the isotopes of lithium has made it seem advisable to recheck the ratio with the new mass spectrograph and improved technique now in use. A previous value of $Li^7/Li^6 = 12.14 \pm 0.4$ was obtained,[1] while 8.1 ± 0.4 observed by Ornstein, Vreeswijk and Wolfsohn[2] from the intensity of the resonance line $\lambda = 6708A$ is perhaps the best of the optical values.

The new mass spectrograph was of the 180° focusing type with a 4 cm radius. It was operated at a pressure of about 3×10^{-6} mm as recorded by an ionization manometer. The filament slit was 0.22×3.0 mm and the collector slit 0.77×5 mm. The resolved current was read with an FP-54 balanced circuit hook-up.

The lithium source was coated on a platinum disk 2 mm in diameter spot-welded to a tungsten filament. The disk was placed in the center of the opening of a nickel washer 1.5 cm in diameter with a 3.5 mm opening; both were maintained at a constant potential of 1080 volts positive to the filament slit.

A typical resolution curve is shown in Fig. 1. The peaks were flat topped and the resolution was complete, the peaks being separated by nearly five times their base width.

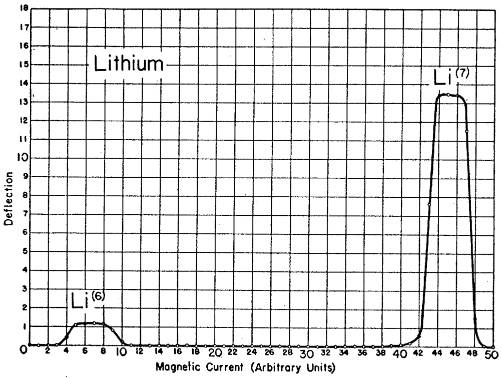

FIG. 1.

The results obtained with two different samples of lithium aluminum silicate tested under widely different conditions as to temperature, thickness of coating, and periods of heating are shown in Table I.

TABLE I. *Abundance ratios Li^7/Li^6.*

No.	No. of check	Average ratio	Average deviation
A	19	11.65	0.09
B	3	11.52	0.06
C	6	11.62	0.06
D	6	11.59	0.07
E	26	11.55	0.05
F	4	11.60	0.02
	Average	11.60 ± 0.06	

Experiment *E* represents a series of checks made with one filament in which the coating was heated to near whiteness for three consecutive periods of 1 hour each. No appreciable change in the ratio was observed. After the results in experiment *F* had been obtained the filament was heated to near the fusion temperature of the silicate for 2 hours; the average of 10 check runs was then 12.20 ± 0.1, while an additional heating period of 1 hour raised the ratio to 12.47 ± 0.1.

Results obtained with the platinum disk from which the lithium aluminum silicate had been carefully scraped and washed after the experiments described in Table I had been made are shown in Table II. The platinum thus contaminated with lithium is an excellent low temperature emitter of positive ions.

Runs *A* and *B* were taken at temperatures just above redness. *C* was made after filament *A* had been heated to bright redness for 1/2 hour. *D* was taken after *B* had been heated a similar period and *E* after an additional $1\frac{1}{2}$ hour

TABLE II. *Abundance ratios Li^7/Li^6 from cleaned Pt disk contaminated with lithium.*

No.	No. of checks	Average ratio	Average deviation
A	5	11.63	0.09
B	5	11.55	0.02
C	13	12.74	0.11
D	13	12.90	0.10
E	6	13.88	0.09

of heating; during this process the Li^+ emission showed definite signs of fatigue.

The results described yield a consistent value of $Li^7/Li^6 = 11.60 \pm 0.06$, which is materially higher than that obtained by optical means.

Insofar as can be told the abundance ratio remains constant for crystalline emitters until heated to near the fusion temperature where an isotope effect of free evaporation is detectable, the lighter isotope then being emitted more readily than the heavy. The effect of free diffusion appears more evident in the impregnated platinum, an appreciable separation of the isotopes being obtained on prolonged heating.

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March 16, 1935.

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[2] Ornstein, Vreeswijk and Wolfsohn, Physica **1**, 53 (1934).

Shower Groups in the Cosmic Radiation

In a recent letter[1] on transition effects, reference was made to observations on showers. These were recorded as sharp jumps superimposed on the photographic trace of the steady ionization current produced in a small, spherical ionization chamber (230 cc volume, 30 atmospheres pressure argon). On the time axis each jump corresponded to 2.6 seconds, which was the period of the recording galvanometer, and could be easily distinguished from statistical fluctuations.

In Table I are recorded the number and rates of occur-

TABLE I. *Rates of occurrence of shower groups.* Total numbers of showers for each group (*N*) and corresponding rates (*N*/min.).

	Size of showers in number of rays: 10–14		15–19		20–29		30–39		>40		Total >20	
Thickness of lead above chamber (cm)	*N*	*N*/min.	*N*	*N*/min.	*N*	*N*/min.	*N*	*N*/min.	*N*	*N*/min.	*N*	*N*/min.
Cambridge; barometer 76, magnetic latitude 53 N												
0	172	0.061	55	0.019	33	0.011	9	0.004	5	0.002	47	0.017
0.64	82	.071	24	.022	11	.010	5	.005	1	.001	17	.016
1.27	147	.116	39	.031	33	.026	6	.005	4	.003	43	.034
3.18	56	.065	18	.021	12	.014	5	.006	1	.001	18	.021
6.66	104	.050	30	.014	27	.013	6	.003	2	.001	35	.017
9.2	22	.030	16	.022	7	.01	2	.003	2	.001	16	.014
14.3	18	.033	10	.018	2	.004	2	.004	2	.004	6	.012
Huancayo; barometer 51.3; magnetic latitude 1 S												
0					30	0.039	11	0.014	10	0.013	51	0.066
0.64					44	.082	14	.026	7	.013	65	.121
1.27					79	.115	22	.032	16	.023	117	.170
3.18					32	.075	13	.030	12	.028	57	.133
6.66					22	.059	7	.019	11	.029	40	.107
9.2					38	.057	13	.02	11	.017	62	.094
14.3					15	.039	4	.01	7	.018	26	.067
Cerro de Pasco; barometer 45; magnetic latitude 1 S												
0					44	0.081	9	0.016	13	0.024	66	0.121
0.64					64	.280	29	.126	22	.092	115	.498
1.27					74	.247	21	.070	23	.077	118	.394
3.18					30	.105	18	.063	39	.090	87	.258
6.66					27	.089	7	.023	15	.027	49	.139
9.2					17	.045	8	.014	12	.020	37	.079
14.3					22	.049	11	.02	12	.021	45	.090