number of α-particles of about 6 cm range when the deuton had an energy of at least 1,200,000 volts. B_2O_3 also yielded α-particles which may however have been produced by the protons rather than the deutons. CaF_2 and NaCl gave a small number of particles of 3.8 and 2.8 cm range, respectively, but these also require further investigation. The remaining targets SiO_2, $NaPO_3$, C, CuS, $Ca(ClO_3)_2$, Au, Pt, brass and mica gave no detectable α-particles.

We are indebted to Dr. M. C. Henderson, who constructed the linear amplifier used in these experiments and who has kindly helped us in many other ways. We are also indebted to the Research Corporation and the Chemical Foundation for their support.

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June 10, 1933.

The Emission of Protons from Various Targets Bombarded by Deutons of High Speed

Deutons (nuclei of H^2) with energies ranging from 600,000 to 1,330,000 volts have been directed against the following targets: carbon, gold, platinum, lithium fluoride, silicon dioxide, sodium phosphate, calcium chlorate, copper sulphide and brass (the backing of the other targets). In addition to the emission of alpha-particles, which we have already reported in the preceding communication, we have observed the emission of protons in large numbers, with various ranges up to more than forty centimeters.

Every target, including gold and platinum which could hardly be expected to suffer nuclear disintegration, yielded protons of about 18 cm range in air. We have been unable to account for this group of protons common to all targets except on the hypothesis that the deuton itself is breaking up, presumably into a proton and a neutron. This assumption implies a lower value for the mass of the neutron than that of Chadwick[1] whose value, however, rests on the assumption that in the disintegration of B^{11} by α-particles, to form N^{14} and a neutron, there is no γ-radiation.

To examine this hypothesis of the instability of the deuton we have observed the relation between the range of the emitted protons and the energy of the bombarding deutons. In the case of gold we observed that when the deuton energy was increased from 1,000,000 to 1,330,000 volts the maximum range of the protons increased approximately from 16.7 cm to 17.9 cm, corresponding to an increased energy of 160,000 volts. This is in accord with the assumption that the proton and neutron fly apart with equal kinetic energies. Realizing that all of these assumptions may be modified by later work, we may nevertheless make a tentative calculation of the mass of the neutron. From the masses of H^1 and H^2 and from the measured energies of the deuton and the emitted proton, the mass of the neutron appears very close to unity. In the case of carbon the change in the energy of the proton was found to be approximately equal to the change in the energy of the deuton which suggests, if our hypothesis is at all correct, that in addition to the dissociation of the deuton there is a change in the carbon nucleus itself.

Aside from this group of protons common to all targets we have observed large numbers of protons from silica and sodium phosphate with ranges in the neighborhood of 12 cm and which were not obtained with the other targets. The investigations have not yet been carried below this range. On the other hand, sodium phosphate and lithium fluoride yielded protons of very high energy. In the former case two long range groups were observed, one of 26 cm and one of 35 cm. Lithium fluoride was not so carefully investigated but protons with ranges as great as 40 cm were observed.

A study of the relation between the number of emitted protons and the energy of the deuton shows that in all cases the emission of protons becomes unobservable when the deuton energy falls below 800,000, and at least in the case of the group common to all targets, there seems to be a very sharp threshold.

We are again indebted to Dr. M. C. Henderson who constructed the linear amplifier used in these experiments and who has kindly helped us in many other ways. We are also indebted to the Research Corporation and the Chemical Foundation for their support.

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[1] Chadwick, Proc. Roy. Soc. **A136**, 692 (1932).

The Masses of the Lithium Isotopes

The mass of Li^6 referred to O^{16} was measured as 6.0145 ± 0.0003 from five spectra by comparison with $H_3{}^2$ by the "doublet" method. The mass of Li^7 was measured from the same spectra as 7.0146 ± 0.0006. The lithium ions were obtained from a heated spiral of flat tungsten strip coated with spodumene. Simultaneously a discharge was run in hydrogen containing a high concentration of the heavy isotope. The hydrogen had been put at the disposal of the writer through the kindness of Professor G. N. Lewis.

Fig. 1 illustrates two $Li^{6+}-H_3{}^{2+}$ doublets.[1] The upper spectrum is one of the five used in the mass determinations. The mass of H^2 had previously been accurately determined in reference to that of helium.[2] The mass of Li^{7+} was measured in reference to that of H_3^{2+} by a less direct and less accurate method than was possible in the case of Li^6. If the mass-scale were strictly linear the mass of Li^7 could be obtained by direct extrapolation. Because of the divergence of the mass-scale from absolute linearity it is necessary to apply a small negative correction to the mass secured on the basis of a linear mass-scale. This correction is easily found and was known from the dispersion data secured from earlier plates. The probable error introduced by this corrected extrapolation may conservatively be taken as ±0.0003 mass units and it has been included in the probable error given in the first paragraph.

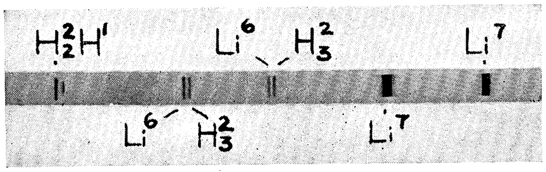

FIG. 1. Mass-spectra of Li^6 and Li^7.

The mass ratio of the isotopes of lithium secured in this investigation does not agree with the value from the band spectrum analysis[3] but it is in good accord with the ratio from Costa's earlier mass-spectrograph measurements.[4]

The author is indebted to Dr. W. F. G. Swann for his interest and helpful discussions. The writer wishes to express his appreciation of the generous gift by Professor G. N. Lewis of the fractionated hydrogen used in this work.

KENNETH T. BAINBRIDGE

Bartol Research Foundation of
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Swarthmore, Pennsylvania,
June 14, 1933.

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[1] These particular spectra cannot be used for the determination of the relative abundance of the lithium isotopes owing to the conditions of voltage existent while the spectra were taken. The fiducial line appears next to $H_2^2H^1$.

[2] K. T. Bainbridge, Phys. Rev. **44**, 57 (1933).

[3] Andrew McKellar, Phys. Rev. **43**, 215 (1933). F. A. Jenkins and Andrew McKellar, Bull. Am. Phys. Soc. **8**, No. 4, 23 (1933).

[4] J. L. Costa, Ann. de Physique **4**, 425 (1925).

Comparison of the Masses of H^2 and Helium

The mass of H^2 has been measured from twelve spectra as 2.01363±0.00004 referred to helium[1] as 4.00216 and 2.01363±0.00008 referred to O^{16} when the probable error in the helium-oxygen ratio is taken into account.

Fig. 1 is a contact print of eight of the spectra used in this comparison of the mass of H^2 with that of helium. The individual spectra are indicated, as in some cases two spectra were taken at the same position of the plate. Each spectrum gives two determinations of the mass of H^2 one from the comparison of He H^{1+} with H_2^2 H^{1+} and another from the comparison of He H^{2+} with H_3^{2+}.

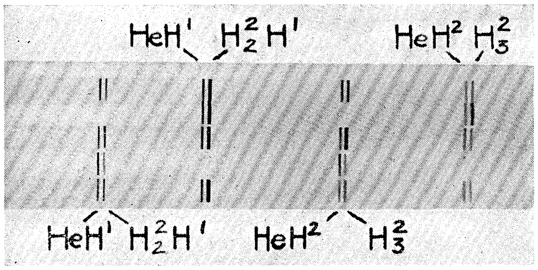

FIG. 1. Mass-spectra for the comparison of the masses of H^2 and He.

The measured positions of the HeH^1 and HeH^2 molecular ions provided the dispersion measurements for these spectra. The mass of H^1 was taken as 1.007775 and the mass of He as 4.00216, as their ratio had been determined from a previous investigation.[2] An error of 1 part in 1000 in the dispersion determination could only introduce an error of 1 part in 200,000 in the determination of the mass of H_2^2 H^{1+} or an error of 1 part in 240,000 in the mass of H_3^{2+}.

This sensitiveness to possible errors in the dispersion constants is an ordinary advantage inherent in the measurement of close doublets. In addition it can be shown that the use of two related doublets, as in the present determination, greatly simplifies the detection and elimination of small systematic errors. Also corrections for nonlinearity of the mass scale appear only in the fifth decimal place if a single mass determination of H^2 is derived from the average of the two values obtained from the "five" doublet and from the "six" doublet. The probable error in the evaluation of the mass of H^2 from twelve spectra was calculated on the basis of twelve average determinations, not twenty-four single values. Moreover it can be shown that the mass of H^2 is evaluated in terms of He alone and the mass determination of H^2 is insensitive to whatever value is selected for H^1 in the range ±0.1 percent from the figure 1.007775. Similarly, in obtaining the dispersion from the separation of the HeH^1 and HeH^2 lines, the final mass determination of H^2 is not sensitive to the value of H^2 used to obtain the mass of HeH^2.

The writer is greatly indebted to Professor G. N. Lewis who very generously gave the writer some "heavy water" containing $H^2 : H^1$ in the approximate abundance range of 1 : 2 to 2 : 3.

KENNETH T. BAINBRIDGE

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Swarthmore, Pennsylvania,
June 14, 1933.

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[1] F. W. Aston, Proc. Roy. Soc. **A115**, 487 (1927).

[2] K. T. Bainbridge, Phys. Rev. **43**, 103 (1933).

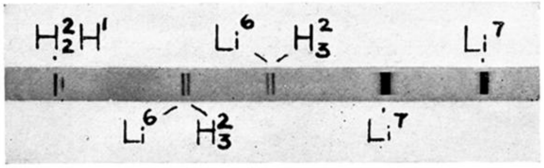

FIG. 1. Mass-spectra of Li^6 and Li^7.