their errors. Essentially the same weights were obtained independently from a consideration of the line widths and rates of drift in the various runs. If we take into account the small uncertainties of $g_J(\mathrm{K})$ and $g_J(\mathrm{Cs})$ we obtain

$$g_J(\mathrm{Cr})=2(1.00081\pm0.00005).$$

DISCUSSION AND CONCLUSION

Our measurements show that the ground state of Cr is a much "better" S state than was indicated by the less accurate optical value for g_J. However, $g_J(\mathrm{Cr})$ does differ by approximately 3 parts in 10^4 from g_s, the pure electron spin g factor. This discrepancy can be due to several factors: (a) interaction terms in the radiative correction,[10,11] (b) nonradiative relativistic correction,[12] (c) diamagnetic correction,[13] and (d) perturbations due to higher states. The effects (a) and (b) have been calculated for some spectra with one or two[11] valence electrons and have been found to be much smaller than 3×10^{-4}. No calculations are available for Cr which has six valence electrons. The diamagnetic correction (c) is negligible[13] (-2×10^{-6} for Cr). The deviation of $g_J(\mathrm{Cr})$ from g_s that has been found is indeed in the direction to be expected from a perturbation (d), but no quantitative conclusions can be drawn until the corrections (a) and (b) are known.

[10] G. Breit, Phys. Rev. **39**, 616 (1932).
[11] W. Perl and V. Hughes, Phys. Rev. **89**, 886 (1953).
[12] G. Breit, Nature **122**, 649 (1928); H. Margenau, Phys. Rev. **57**, 383 (1940).
[13] W. E. Lamb, Phys. Rev. **60**, 817 (1941).

TABLE III. Experimental results used in the derivation of $g_J(\mathrm{K})$ and $g_J(\mathrm{Cs})$. The quantities designated A to E are experimental results obtained by various investigators. Values for $g_J(\mathrm{K})/g_l$ and $g_J(\mathrm{Cs})/g_l$ are derived from these in the manner shown in the last two rows. Throughout the text of the present paper, wherever the g_J's of K and Cs have been used, g_l has been set equal to 1, as is done in optical spectroscopy.

Symbol	Quantity	Value
A	$2g_l/g_p$	$-657.475\ \pm0.008$[a]
B	$g_J(\mathrm{K})/g_p$	$-658.2274\ \pm0.0023$[b]
C	$g_p/g_J(\mathrm{Cs})$	$-(15.1911\ \pm0.0003)\times10^4$[c]
D	$g_J(\mathrm{Cs})/g_J(\mathrm{Na})$	1.000134 ± 0.000007[d]
E	$g_J(\mathrm{Na})/g_J(\mathrm{K})$	$1.00000\ \pm0.00002$[d]
$2B/A$	$g_J(\mathrm{K})/g_l$	$2(1.00114\ \pm0.00001)$
Av of $2/CA$ and $2BDE/A$	$g_J(\mathrm{Cs})/g_l$	$2(1.00125\ \pm0.00003)$

[a] J. H. Gardner and E. M. Purcell, Phys. Rev. **76**, 1262 (1949); J. H. Gardner, Phys. Rev. **83**, 996 (1951).
[b] P. Franken and S. Koenig, Phys. Rev. **88**, 199 (1952).
[c] H. Taub and P. Kusch, Phys. Rev. **75**, 1481 (1949).
[d] See reference 6.

Apart from these theoretical considerations, it should be mentioned that, with the accurately known g_J of the ground state, the Zeeman splittings of the resonance lines of Cr I (e.g., of the transitions ${}^7S_3-{}^7P^\circ_{2,3,4}$ at 4290A, 4275A, and 4254A) are now very suitable for the calibration of magnetic fields in optical Zeeman spectroscopy.[14]

We are much indebted to Dr. G. Herzberg for helpful criticism.

[14] See, e.g., the pattern of λ4254A as reproduced in A. Sommerfeld, *Atombau und Spektrallinien* (F. Vieweg & Sohn, Braunschweig, 1931), fifth edition, Vol. I, p. 523.

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The 7.68-Mev State in C^{12}

D. N. F. DUNBAR,* R. E. PIXLEY, W. A. WENZEL, AND W. WHALING
Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, California
(Received July 21, 1953)

Magnetic analysis of the alpha-particle spectrum from $N^{14}(d,\alpha)C^{12}$ covering the excitation energy range from 4.4 to 9.2 Mev in C^{12} shows a level at 7.68±0.03 Mev. At $E_d=620$ kev, $\theta_{\mathrm{lab}}=90°$, transitions to this state are only 6 percent of those to the level at 4.43 Mev.

SALPETER[1] and Öpic[2] have pointed out the importance of the $Be^8(\alpha,\gamma)C^{12}$ reaction in hot stars which have largely exhausted their central hydrogen. Hoyle[3] explains the original formation of elements heavier than helium by this process and concludes from the observed cosmic abundance ratios of $O^{16}:C^{12}:He^4$ that this reaction should have a resonance at 0.31 Mev or at 7.68 Mev in C^{12}.

An early measurement of the range of the alpha particles from $N^{14}(d,\alpha)C^{12}$ indicated a level in C^{12} at 7.62 Mev.[4] However, a recent magnetic analysis of this reaction failed to detect a transition to any level in this region of excitation,[5] nor did the level show up in the neutron spectrum[6] from $B^{11}(d,n)C^{12}$. From the

* On leave from the University of Melbourne, Melbourne, Australia.
[1] E. E. Salpeter, *Annual Review of Nuclear Science* (Annual Reviews, Inc., Stanford, 1953), Vol. 2, p. 41.
[2] E. J. Öpic, Proc. Roy. Irish Acad. **A54**, 49 (1952).
[3] F. Hoyle (private communication).
[4] M. G. Holloway and B. L. Moore, Phys. Rev. **58**, 847 (1940).
[5] R. Malm and W. W. Buechner, Phys. Rev. **81**, 519 (1951).
[6] W. M. Gibson, Proc. Phys. Soc. (London) **A62**, 586 (1949); V. R. Johnson, Phys. Rev. **86**, 302 (1952).

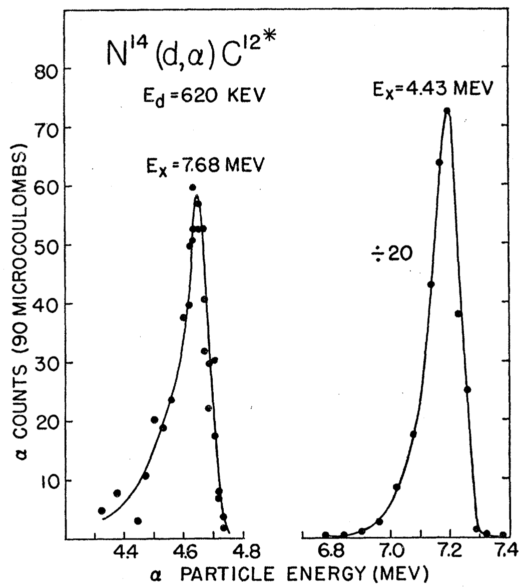

FIG. 1. Alpha spectrum from $N^{14}(d,\alpha)C^{12}$ obtained with a thick NH_3 target. No other groups were observed in the range $E_\alpha=3.7-7.4$ Mev of magnitude 1 percent of the group to the 4.43-Mev state. The spectrometer was set at $\theta_{lab}=90°$.

$Be^9(\alpha,n)C^{12}$ neutron spectrum there is evidence for a level near 7.5 Mev,[7] and inelastic proton scattering from carbon also gives a level at 7.5±0.4 Mev.[8] Gamma rays accompanying the $Be^9(\alpha,n)C^{12}$ reaction have been interpreted as a cascade from a state at 7.59±0.07 Mev; direct transitions to the ground state of C^{12} are not observed.[9]

We have determined the position of this level by observing the spectrum of alpha particles from the $N^{14}(d,\alpha)C^{12}$ reaction with a double-focusing magnetic spectrometer. Because of its large aperture of 0.007 steradian, this spectrometer is particularly suited to the measurement of very weak groups. A thick target of NH_3 frozen on a copper target cooled with liquid nitrogen was bombarded with 620-kev deuterons from the electrostatic generator. The energy spectrum of the alpha particles emitted at 90° is shown in Fig. 1. The higher energy group is from the transition to the state in C^{12} at 4.43 Mev. No other groups were observed between 7.4 and 3.7 Mev; a group 1 percent as strong as the transition to the 4.43-Mev level could have been detected.

[7] Guier, Bertini, and Roberts, Phys. Rev. **85**, 426 (1952).

[8] R. Britten, Princeton University Report, NYO-971, June 1951 (unpublished).

[9] Beghian, Halban, Husain, and Sanders, Phys. Rev. **90**, 1129 (1953).

Identification of this group as alpha particles was made by placing nuclear track plates in the focal plane of the spectrometer and measuring the range of these particles of known *mv/e*. To make certain that this weak group does not come from any likely contamination in the target, the measurements were repeated with targets of ice, carbon, and with the target warm. This group did not appear. It did appear with targets prepared from two different samples of ammonia, one of 99.98 percent purity according to the Mathiesson Company.

The energy of each group is taken to be that of the half-maximum point on the leading edge with an assigned uncertainity of ±one quarter of the full width of the rise. A more exact determination of the energy of these groups by fitting the curves to the theoretical thick-target spectrum shape is not worth while because of the poor statistical accuracy of the low-energy group. The energy scale was calibrated against the energy of the group to the 4.43-Mev state which was calculated from the MIT value[5] for the Q of this transition. The difference in energy of the two groups is 2.438±0.025 Mev, and using the value[10] 4.431 ±0.013 for the first-excited state, we find the energy of excitation in C^{12} to be 7.68±0.03 Mev.

A limit can be set on the width of this state by an examination of the spectrum. The slope of the leading edge of the thick target spectrum is determined by the natural line width, the resolution of the spectrometer, and the energy spread $(dE_2/d\theta)\Delta\theta$ introduced by the finite aperture $\Delta\theta$. The results in Fig. 1 were taken with very low resolution, $E/\Delta E=117$, in order to obtain the maximum counting rate for the weak group. With nuclear plates as detector it was possible to increase the resolution of the spectrometer so that it made a negligible contribution to the width of the leading edge. The width of the edge was then found to be 33 kev; the value calculated from $(dE_2/d\theta)$ and the observed width of the edge for the high-energy group is 31 kev. This discrepancy is well within the limits of our experimental accuracy, and we conclude that this state has a natural width not noticeably greater than the width of the 4.43-Mev state. A width of 25 kev could have been detected. Thus the decay into Be^8 and He^4 with an energy of 0.31 Mev is apparently slowed down by the penetration factor which is indeed expected to be small.

We are indebted to Professor Hoyle for pointing out to us the astrophysical significance of this level.

[10] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **24**, 321 (1952).