A MORE ACCURATE MASS FOR 8He

Authors
Cerny, Joseph
Jelley, N.A.
Hendrie, D.L.
et al.

Publication Date
1974-08-01

Submitted to Physical Review C

LBL-2984
Preprint c.2

A MORE ACCURATE MASS FOR ^{8}He

Joseph Cerny, N. A. Jelley, D. L. Hendrie, C. F. Maguire,
J. Mahoney, D. K. Scott and R. B. Weisenmiller

August, 1974

Prepared for the U. S. Atomic Energy Commission
under Contract W-7405-ENG-48

A MORE ACCURATE MASS FOR $^{8}He^{\dagger}$

Joseph Cerny, N. A. Jelley, D. L. Hendrie, C. F. Maguire,
J. Mahoney, D. K. Scott and R. B. Weisenmiller

Department of Chemistry and
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

August 1974

ABSTRACT

The $^{26}Mg(\alpha, ^{8}He)^{22}Mg$ reaction was reinvestigated at a bombarding energy of 110.6 MeV with a magnetic spectrometer-multiwire proportional counter detection system, leading to an improved value for the mass-excess of ^{8}He of 31.57 ± 0.03 MeV.

NUCLEAR REACTIONS: $^{26}Mg(\alpha, ^{8}He)^{22}Mg$, E = 110.6 MeV; ^{8}He measured mass-excess; compared mass predictions.

With the advent of large solid-angle magnetic spectrometers, multi-neutron transfer reactions, such as (α, ^{8}He) or (^{3}He, ^{8}He), producing highly neutron-deficient reaction products will be of increasing experimental interest. As an example, quite recently Robertson et al[1] measured the masses of ^{8}C and ^{20}Mg via the (α, ^{8}He) reaction on ^{12}C and ^{24}Mg. Since such studies rely directly on the previously measured[2-3] mass of ^{8}He, it was felt to be of interest to improve the accuracy of the earlier results.

Two different experimental approaches have been employed in determining the mass-excess of ^{8}He. Cerny et al[2] utilized an 80-MeV alpha-particle beam and counter-telescope techniques to observe the $^{26}Mg(\alpha, {}^{8}He)^{22}Mg$ reaction [Q-value $\sim$-45 MeV]. Twelve ^{8}He events populating the ^{22}Mg ground state were detected [$d\sigma/d\Omega$ (14^{o}) $\sim$ 50 nb/sr lab] leading to a mass-excess for ^{8}He of 31.65 ± 0.12 MeV. In addition, Batusov et al[3] obtained the mass-excess of ^{8}He by observing in photographic emulsions the production (and decay) of ^{8}He nuclei produced by capture of stopped π^{-} mesons in carbon and oxygen nuclei. Eight such capture events were registered in which all reaction products were charged particles; kinematic analysis of these events led to a ^{8}He mass-excess of 31.0 ± 0.4 MeV, in agreement with the Berkeley result.

This reinvestigation of the mass-excess of ^{8}He again employed the $^{26}Mg(\alpha, {}^{8}He)^{22}Mg$ reaction. An energy-analyzed 110.6 MeV α-particle beam from the Lawrence Berkeley Laboratory 88-inch cyclotron was used to bombard a 1.2 mg/cm^{2} ^{26}Mg target. Reaction products were detected at 10^{o} lab with a 1.4 msr solid angle in the focal plane of a magnetic spectrometer with a position sensitive proportional counter backed by a plastic scintillator[4].

Unambiguous particle identification was obtained by measuring $B\rho$ (position), differential energy loss ($\Delta E/\Delta X$), time of flight (TOF) and the pulse height from a dynode of the scintillator (denoted E and proportional to energy, but with a further dependence on charge and mass). The time of flight measurement was obtained from the anode signal of the plastic scintillator and the cyclotron rf signal and had a resolution (FWHM) of 5 nsec. Other typical resolutions were $\frac{\Delta E}{\Delta X} \sim 15\%$ and energy resolution $^{\delta E}/_{E} \sim 0.25\%$.

Due to the low yield of ^{8}He reaction products, it was necessary for the detection system to eliminate continuum $^{4}He^{+}$ events which would have obscured the $^{8}He^{+2}$ events of interest. For a given $B\rho$ value, both of these ions have essentially the same time-of-flight and $^{\Delta E}/_{\Delta X}$ loss, so that we needed to employ the plastic scintillator dynode output to reject the substantial background of $^{4}He^{+}$ events on the basis of their lower energy (the $^{8}He^{+2}$ energy is twice that of $^{4}He^{+}$). Final energy spectra of different particle groups were obtained by setting gates on $\Delta E/\Delta X$, TOF and E.

The energy calibration of the focal plane was obtained by concurrently measuring ^{6}He events from the $^{26}Mg(\alpha,{}^{6}He)^{24}Mg$ reaction. Transitions to the $^{24}Mg^{*}$(6.010 MeV) state[5] lie an amount equivalent to only $\sim$ 200 keV away from the $^{26}Mg(\alpha,{}^{8}He)^{22}Mg$ (ground state) reaction. The dispersion across the focal plane was obtained from the positions of the transitions populating the $^{26}Mg(\alpha,{}^{6}He)^{24}Mg^{*}$ (1.369, 4.123 and 6.010 MeV) states.

Figure 1 presents the energy spectrum from the $^{26}Mg(\alpha,{}^{8}He)^{22}Mg$ reaction. As in the earlier experiment[2] at 80 MeV, transitions were observed to both the ground and the first excited state[5] of ^{22}Mg; the ground state cross section at 110.6 MeV was $\sim$ 10nb/sr lab. A strong transition was also observed to a new state (or states) at 8.6 MeV excitation. This state should still be of T = 1 character since Coulomb displacement energy calculations[6] place the lowest T = 2 state in ^{22}Mg near 14.0 MeV excitation.

These results establish a new mass-excess for ^{8}He of 31.57 ± 0.03 MeV (based on a ^{22}Mg mass-excess of -396 ± 2 keV[7]), which agrees very well with the earlier measurements. ^{8}He is then bound by 2.17 MeV with respect to its lowest break-up channel of ^{6}He + 2n; since no evidence for transitions to a particle stable first excited state of ^{8}He has been observed in these data, it may well be that it lies above this threshold (note Barker's calculations[8] on the spectrum of ^{9}Li, whose first excited state is at 2.69 MeV).

The mass of ^{8}He has considerable theoretical interest, initially because of questions of the possible existence of a bound state, and currently as one of the important tests of theories predicting binding energies of light nuclei, particularly with regard to the symmetry energy of the force employed. Table I[8,9] presents results from a broad sample of the more successful[10] of these theoretical predictions of the mass-excess of ^{8}He (where applicable, calculations were updated using the 1971 atomic mass table[11]). Of the calculations prior to the first measurement of the mass-excess of ^{8}He, the approach of Goldanskii[9] and the intermediate coupling calculations of Barker[8] agree best with experiment. The more recent theoretical calculations generally predict masses for a number of even helium isotopes, in many cases so far substantially disagreeing with experiment.

Finally, this more accurate mass-excess for ^{8}He revises the measured mass-excesses[1] of ^{8}C and ^{20}Mg to be 35.38 ± 0.17 MeV and 17.82 ± 0.18 MeV, respectively. Greater accuracy in the latter result would be of interest as a further test of the $1d_{5/2}$ shell Coulomb displacement energy calculations of Hardy *et al*[6] which predict a mass-excess of 17.51 MeV for ^{20}Mg. This approach has been remarkably successful so far, predicting the mass-excesses of ^{19}Na, ^{21}Mg, ^{23}Al and ^{25}Si with a maximum deviation (ignoring errors) of 30 keV.

REFERENCES

† Work performed under the auspices of the U. S. Atomic Energy Commission.

1. R. G. H. Robertson, S. Martin, W. R. Falk, D. Ingham and A. Djaloeis, Phys. Rev. Letters 32, 1207 (1974).
2. J. Cerny, S. W. Cosper, G. W. Butler, R. H. Pehl, F. S. Goulding, D. A. Landis and C. Detraz, Phys. Rev. Letters 16, 469 (1966).
3. Yu. A. Batusov, S. A. Bunyatov, V. M. Sidorov and V. A. Yarba, Phys. Letters 22, 487 (1966); and Sov. Journal of Nucl. Phys. 7, 20 (1968).
4. B. G. Harvey, J. Mahoney, F. G. Pühlhofer, F. S. Goulding, D. A. Landis, J. C. Faivre, D. G. Kovar, M. S. Zisman, J. R. Meriwether, S. W. Cosper and D. L. Hendrie, Nucl. Instr. Methods 104, 21 (1972); H. Homeyer, J. Mahoney and B. G. Harvey, ibid., 118, 311 (1974).
5. P. M. Endt and C. van der Leun, Nucl. Phys. A214, 1 (1973).
6. J. C. Hardy, H. Brunnader, J. Cerny and J. Jänecke, Phys. Rev. 183, 854 (1969).
7. J. C. Hardy, H. Schmeing, W. Benenson, G. M. Crawley, E. Kashy and H. Nann, Phys. Rev. C9, 252 (1974).
8. F. C. Barker, Nucl. Phys. 83, 418 (1966).
9. V. I. Goldanskii, Soviet Physics JETP 11, 1179 (1960).
10. Compare, for example, V. F. Rybachenko and A. A. Sadovoi, Sov. Journal of Nucl. Phys. 12, 384 (1971) or A. I. Steshenko and G. F. Filippov, Sov. Journal of Nucl. Phys. 14, 403 (1972).
11. A. H. Wapstra and N. B. Gove, Nuclear Data A9, 267 (1971).

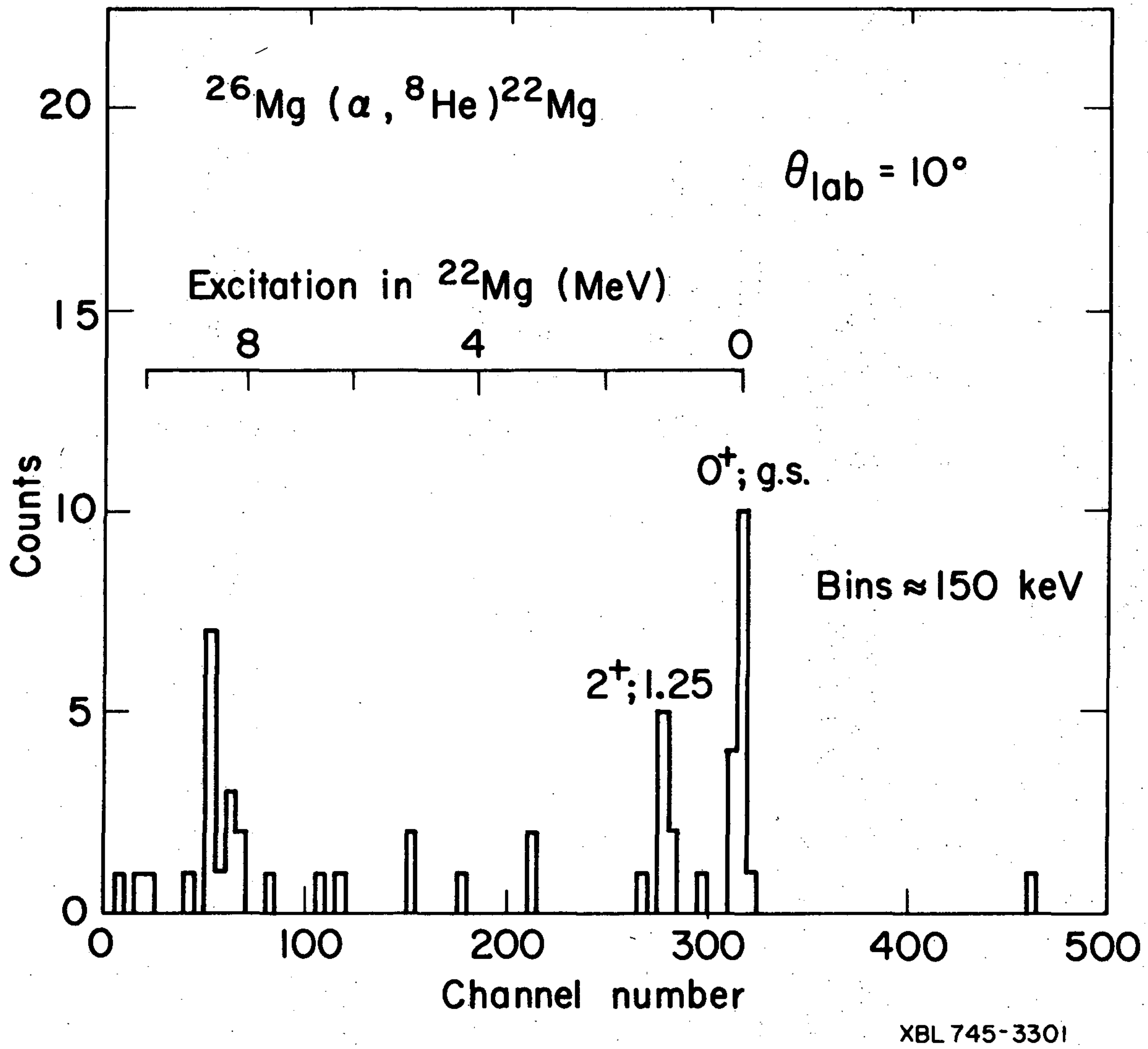
Table I. Theoretical Predictions of the Mass-Excess of ^{8}He.

[Experimental value = 31.57 ± 0.03 MeV; unbound at 33.74 MeV]

Calculated Mass-Excess (MeV)	Type of Calculation	Reference
32.2 ± 0.4	neutron pairing energy systematics	V. I. Goldanskii, ref. 9.
34.2 ± 2	symmetry and pairing energy systematics	J. Jänecke, Nucl. Phys. 73, 97 (1965).
29.8	independent particle model (recursion relations)	G. T. Garvey and I. Kelson, Phys. Rev. Letters 16, 197 (1966).
31.2	intermediate coupling shell model	F. C. Barker, ref. 8.
∿ 30.6	Thomas-Fermi calculation	R. J. Lombard, Phys. Letters 35B, 493 (1971).
33.4	constrained spherical Hartree-Fock calculation	X. Campi and D. W. Sprung, Nucl. Phys. A194, 401 (1972).
29.3	SU_4	C. Maguin, Nuovo Cimento 19A, 638 (1974).

FIGURE CAPTIONS

Fig. 1. The energy spectrum from the $^{26}Mg(\alpha,{}^{8}He)^{22}Mg$ reaction at 10° lab using 110.6 MeV incident α-particles.



^{26}Mg (α, ^{8}He)^{22}Mg
θlab = 10°
Excitation in ^{22}Mg (MeV)
8
4
0
0+; g.s.
2+; 1.25
Bins ≈ 150 keV
Counts
20
15
10
5
0
0
100
200
300
400
500
Channel number
XBL 745-3301

Fig. 1

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720