Lawrence Berkeley National Laboratory

Recent Work

Title

SINGLE-PARTICLE PROTON ADMIXTURES IN CORE-EXCITED STATES OP zorBi

Permalink

https://escholarship.org/uc/item/3qm4171c

Authors

Glashausser, C
Hendrie, D.L.
McClatchie, E.A.

Publication Date

1970-10-01

eScholarship.org Powered by the California Digital Library
University of California

Submitted to Physics Letters

UCRL-19993
Preprint

RECEIVED
LAWRENCE
RADIATION LABORATORY

NOV 13 1970

LIBRARY AND
DOCUMENTS SECTION

C. 2

SINGLE-PARTICLE PROTON ADMIXTURES IN CORE-EXCITED STATES OF ^{207}Bi

C. Glashausser, D. L. Hendrie,
and E. A. McClatchie

October 1970

AEC Contract No. W-7405-eng-48

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 5545

LAWRENCE RADIATION LABORATORY
UNIVERSITY of CALIFORNIA BERKELEY

UCRL-19993

C. 2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

SINGLE-PARTICLE PROTON ADMIXTURES IN CORE-EXCITED STATES OF ^{207}Bi*

C. GLASHAUSSER
Department of Physics
Rutgers University, New Brunswick, New Jersey 08903
and
D. L. HENDRIE and E. A. McCLATCHIE†
Lawrence Radiation Laboratory
University of California, Berkeley, California 94720

ABSTRACT

At least 18 states up to 3.5 MeV of excitation have been observed in the $^{206}Pb(^{3}He,d)^{207}Bi$ reaction at 35 MeV. The experimental spectrum and spectroscopic factors are in fair agreement with the predictions of the weak-coupling model up to an excitation energy of 2.5 MeV.

*Work supported in part by the National Science Foundation and the United States Atomic Energy Commission.

†Present address: ARKON Laboratory, Berkeley, California.

The initial success of shell-model calculations in the region of ^{208}Pb makes this a fertile region for more detailed study. Even a simple weak-coupling model appears to work well for nuclei one nucleon removed from ^{208}Pb,[1,2] although attempts to apply this model to ^{205}Tℓ (one proton hole in a ^{206}Pb core) have not yielded good results. However, the introduction of core states of more than one phonon via an intermediate coupling model[3] have given good agreement with transition rates and spectroscopic factors for low-lying states in ^{205}Tℓ. In the present investigation, we have studied the single-particle structure of states in ^{207}Bi with the ^{206}Pb(^{3}He,d)^{207}Bi reaction. The results are compared with the predictions of both weak-coupling and intermediate-coupling models in which a proton particle is coupled to ^{206}Pb core states.

The experiment was performed at the Berkeley 88" cyclotron with a 35 MeV ^{3}He beam, energy-analyzed to 0.05%. The experimental arrangements have been described previously.[4] In the present experiment the detector telescopes consisted of a 0.25 mm phosphorous-diffused ΔE counter and a 4 mm Si (Li) E counter. The total energy resolution of 40 keV included a large contribution from target thickness. The targets were 300 μg/cm^2 self-supporting foils of ^{206}Pb and ^{208}Pb of isotopic enrichment 97.2% and 99.5% respectively. The ^{208}Pb data and ^{206}Pb data were taken alternately during the run. This procedure provided energy calibrations, relative cross-section normalizations, and identification of angular-momentum transfers without recourse

to calculations such as DWBA predictions.

The excitation energies listed in Table I are good to ±15 keV and agree well with the high resolution data of Alford[5] at Rochester. He observed states up to 3.13 MeV of excitation at a lab angle of 50°; of those states, only a 2.93-MeV doublet with a splitting of 15 keV was not resolved in the present work. Although many states up to 2.4 MeV of excitation have previously been identified[6] in ^{207}Bi by observation of gamma decays, the states above 1.14 MeV of excitation have been observed only in the (^{3}He,d) reaction.[7] Spins have previously been assigned[6] to the states at 0.0 ($9/2^-$), 0.75 ($7/2^-$), 0.89 ($9/2^-$), 0.99 ($7/2^-$), and 1.14 MeV ($5/2^-$).

Angular distributions for the strongly excited states in ^{207}Bi are shown in Fig. 1. The solid lines drawn through these data are experimental curves drawn through the data for the appropriate state in the ^{208}Pb(^{3}He,d)^{209}Bi reaction. The spins of the ^{209}Bi states have been previously identified. Spectroscopic factors (Table I) have been obtained simply by taking the ratio of the ^{207}Bi cross section to the ^{209}Bi cross section for states of the same orbital angular momentum. Thus, the ^{209}Bi spectrosopic factors have been assumed to be 1.0.

The ^{207}Bi spectrum is considerably more complicated than the spectrum of ^{209}Bi. The $2f_{7/2}$ single particle proton state and the $|^{206}\text{Pb}\ 2^+, 1h_{9/2}\rangle$ weak coupling configurations are dominant in the multiplet of four states at about 0.9 MeV. The $i_{13/2}$ single-particle state at 1.62 MeV is hardly shifted from

its position in ^{209}Bi. Between 1.7 and 2.6 MeV, the ^{207}Bi states are weakly excited but there are no ^{209}Bi states in this region. At higher excitations, the single-particle $2f_{5/2}$ and $3p_{3/2}$ states in ^{209}Bi appear split over many levels in ^{207}Bi. The spin assignments which have been suggested in Table I for these states are tentative. The discrimination between $\ell = 1$ and $\ell = 3$ transfer was complicated by the presence of carbon and oxygen contaminants in the crucial forward angle region; certainly no distinction could be made between $j = \ell + 1/2$ and $j = \ell - 1/2$. The 2.78-MeV state and the 2.93-MeV doublet all appear to be populated by $\ell = 3$ transfer, but the agreement with the ^{209}Bi data is only fair. If these assignments are correct, these three states exhaust 90% of the expected $f_{5/2}$ strength, and the states at 3.03, 3.13, 3.32, and 3.45 MeV (a doublet) are most likely populated by $\ell = 1$ transfer. (The weakest of these, the 3.03-MeV state, has a spectroscopic factor of 0.30 if it is an $f_{5/2}$ transfer. In addition, the $\ell = 1$ curve fits the angular distributions for the 3.32 and 3.45 MeV states much better than $\ell = 3$.) The density of states above 3.5 MeV is too large to permit reliable extraction of cross sections in this region where $3p_{1/2}$ strength is expected.

The weak coupling model calculation follows the description of Mottelson[1] and its successful application by Auerbach and Stein[2] to ^{209}Bi. The core states included were those most strongly excited in inelastic scattering on ^{206}Pb, viz., the states at 0.0 (0^+), 0.80 (2^+), 2.65 (3^-), 3.77 (5^-), 4.12 (2^+),

and 4.37 (4^+); values of B(EL) were taken from Alster.[8] The six lowest-lying particle orbits ($1h_{9/2}$, $2f_{7/2}$, $1i_{13/2}$, $2f_{5/2}$, $3p_{3/2}$, and $3p_{1/2}$) were included. Single-particle energies were chosen to be equal to those used by Auerbach and Stein.[2] The radial integrals were also set at their value, 40 MeV; calculations with higher values did not qualitatively change the predicted spectrum.

The calculated spectrum and spectroscopic factors are compared with the experimental values in Fig. 2. The calculation correctly predicts the appearance of four states around 0.9 MeV; the $|^{206}\text{Pb}\ 2^+, 1h_{9/2}\rangle$ states are observed via the admixture of the appropriate single particle components. The ordering of the four spins is not correct, and the strengths in the two $7/2^-$ states are inverted, but these details should be sensitive to the single-particle energies which were not adjusted. The $13/2^+$ state at 1.6 MeV appears with about the right strength, and the weak excitation of states around 2 MeV is also qualitatively predicted. At higher excitations, however, the model fails completely. Only one strong state of each spin, 5/2, 3/2, and 1/2, is predicted around 3 MeV, whereas at least seven strong states are experimentally found between 2.75 and 3.5 MeV. Since there are many more possible core states in ^{206}Pb than the ones we have included, this disagreement is not unexpected.

Intermediate-coupling calculations for ^{207}Bi have recently been reported by Bradley and Meder.[9] Core states with up to

three quadrupole phonons were included but only the $h_{9/2}$ and $f_{7/2}$ single-particle states were coupled to them. Thus the predicted spectroscopic factors for only $9/2^-$ and $7/2^-$ states are shown in Fig. 2. The agreement with the position of the experimental levels is good for all four states, and the strengths of the two $9/2^-$ transitions are correctly predicted. However, the stronger $7/2^-$ state is again predicted to be the lower one, as in the weak-coupling calculation, but in disagreement with the data.

References

1. B. R. Mottelson, Proc. Intern. Conf. on Nuclear Structure, Tokyo (1967) p. 87.

2. N. Auerbach and N. Stein, Phys. Letters 28B, 628 (1969).

3. A. Covello and G. Sartoris, Nucl. Phys. A93, 481 (1967).

4. E. A. McClatchie, C. Glashausser, and D. L. Hendrie, Phys. Rev. 1, 1828 (1970).

5. W. P. Alford, private communication.

6. P. K. Hopke, R. A. Naumann, and E. H. Spejewski, Phys. Rev. 187, 1709 (1969); I. Bergström, C. J. Herrlander, P. Thieberger, and J. Blomqvist, Phys. Rev. 181, 1642 (1969).

7. E. A. McClatchie, C. Glashausser, and D. L. Hendrie, Bull. Am. Phys. Soc. 14, 853 (1969); D. Rieck, E. Grosse, J. Keller, and W. R. Hering, Proc. Conf. on Nuclear Structure, Montreal (1969) p. 55.

8. J. Alster, Physics Letters 25, 459 (1967).

9. A. M. Bradley and M. R. Meder, Phys. Rev. 1, 1723 (1970).

Figure Captions

Fig. 1. Relative cross sections for strongly excited states observed in the $^{206}Pb(^{3}He,d)^{207}Bi$ reaction at 35 MeV. The solid lines are curves drawn through the angular distributions for the $^{208}Pb(^{3}He,d)^{209}Bi$ reaction.

Fig. 2. Comparison of the experimental spectroscopic factors with the predictions of the weak-coupling and intermediate coupling models. The unperturbed positions of the various components are shown in the "zeroth order" column.

Table I. Spectroscopic Factors

E_x (MeV)	J^π	S	ΔS
0.0	9/2-	0.80	0.15
0.75	7/2-	0.09	0.02
0.89	9/2-	0.25	0.10
0.99	7/2-	0.79	0.05
1.14	5/2-	0.02	0.01
1.61	13/2+	0.90	0.15
1.75	?	--	
1.85	?	--	
1.95	?	--	
2.12	?	--	
2.33	?	--	
2.78	(5/2-)	0.48	0.05
2.93 (doublet)	(5/2-)	0.42	0.04
3.03	(3/2-)	0.12	0.02
3.13	(3/2-)	0.15	0.02
3.32	(3/2-)	0.45	0.02
3.45	(3/2-)	0.27	0.02

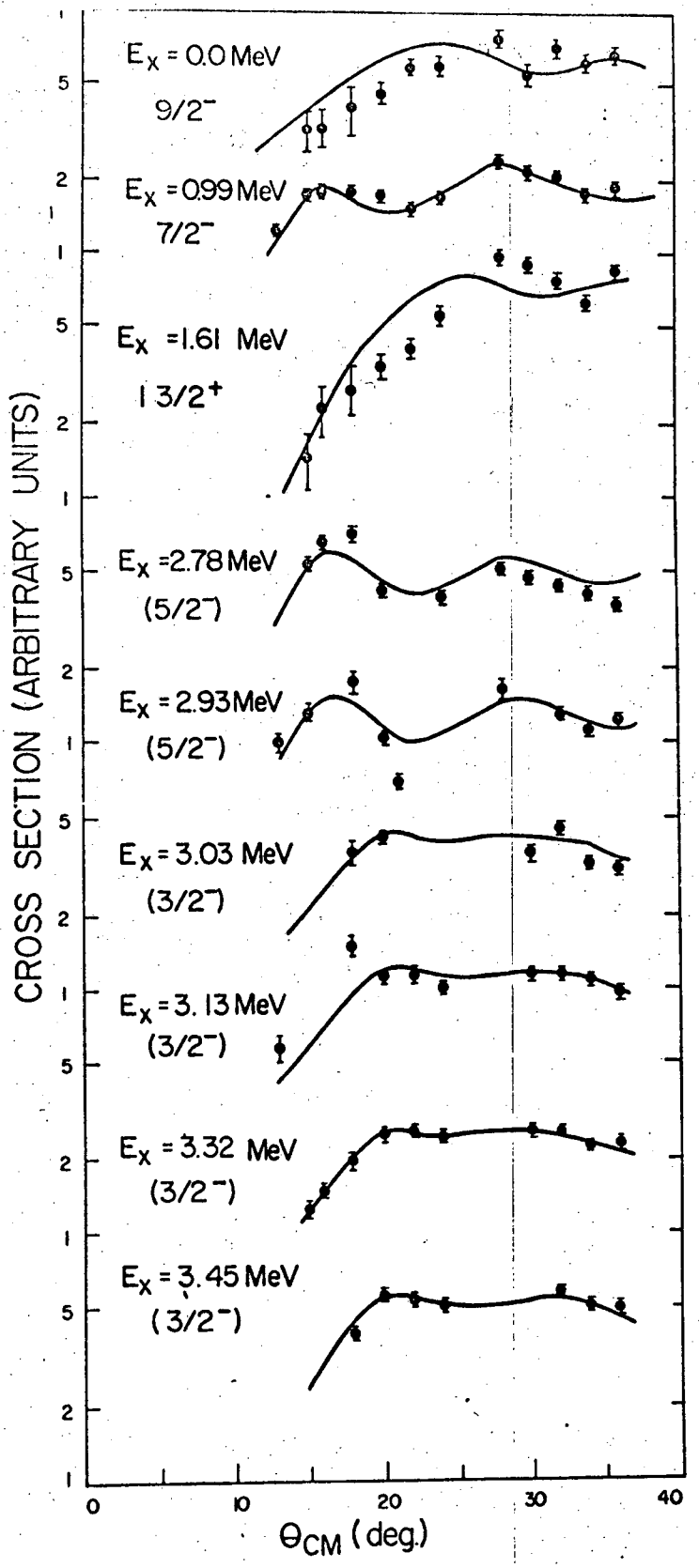
E_x = 0.0 MeV
9/2⁻
E_x = 0.99 MeV
7/2⁻
E_x = 1.61 MeV
1 3/2⁺
E_x = 2.78 MeV
(5/2⁻)
E_x = 2.93 MeV
(5/2⁻)
E_x = 3.03 MeV
(3/2⁻)
E_x = 3.13 MeV
(3/2⁻)
E_x = 3.32 MeV
(3/2⁻)
E_x = 3.45 MeV
(3/2⁻)
CROSS SECTION (ARBITRARY UNITS)
0
10
20
30
40
Θ_{CM} (deg.)

Fig. 1

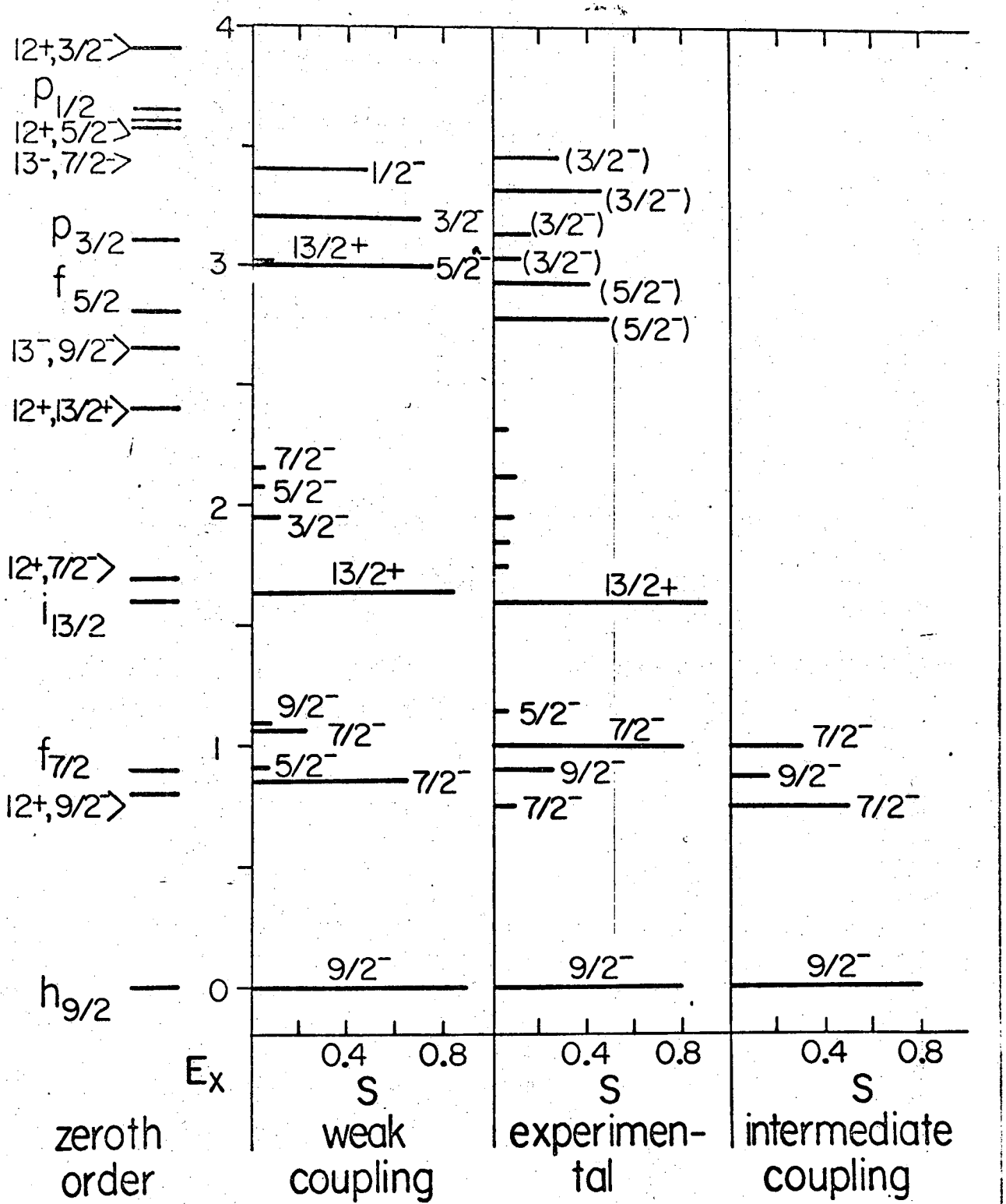
12+,3/2-
p1/2
12+,5/2-
13-,7/2-
p3/2
f5/2
13-,9/2-
12+,13/2+
12+,7/2-
i13/2
f7/2
12+,9/2-
h9/2
4
3
2
1
0
Ex
1/2-
3/2-
13/2+
5/2-
7/2-
5/2-
3/2-
13/2+
9/2-
7/2-
5/2-
7/2-
9/2-
0.4
0.8
S
zeroth order
S
weak coupling
(3/2-)
(3/2-)
(3/2-)
(3/2-)
(3/2-)
(5/2-)
(5/2-)
13/2+
5/2-
7/2-
9/2-
7/2-
9/2-
S
experimental
7/2-
9/2-
7/2-
S
intermediate coupling

Fig. 2

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

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